SYNERGISTIC EFFECTS AMONG LEADING INDICATORS OF CONSTRUCTION

SAFETY MANAGEMENT

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SYNERGISTIC EFFECTS AMONG LEADING INDICATORS OF CONSTRUCTION SAFETY MANAGEMENT

A

DISSERTATION

Presented to the Faculty

of the University of Alaska Fairbanks

in Partial Fulfillment of the Requirements

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DOCTOR OF PHILOSOPHY

By

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Abstract

Safety performance in the construction industry has improved significantly since the Occupational Safety and Health Act was enacted in 1970. Despite these improvements, annual accident statistics indicate the construction industry remains one of the most dangerous for workers. However, there are some construction companies that defy these statistics and have an exemplary safety record. Many of these companies have adopted a zero-accident vision and measure their safety performance using both leading and lagging indicators. Safety performance has traditionally been measured with only lagging indicators that have included recordable injury rates, experience modification rates, days-away-restricted-transferred, among many others. Unfortunately these indicators are recorded after an accident has occurred, resulting in management only being able to take a reactive approach. Conversely, a proactive approach uses leading indicators to alert management before an accident occurs.

Previous research has found thirteen leading indicators that are connected to a strong safety performance for construction projects. However, several researchers and safety management experts recommend only monitoring and measuring two to three indicators on a project due to the resources required. Determining which leading indicators to monitor can be a difficult process for management new to this proactive approach. In an effort to help the construction industry, the first phase of data collection for my dissertation benchmarked the knowledge and use of leading indicators by interviewing twenty-five small contractors. The purpose of the interview was to identify leading indicators used by each small contractor and identify challenges to implementation when an indicator was not being used. The results were analyzed to find the total percentage of use for each indicator and their relationship to the contractor's total recordable injury rates. Two leading indicators were found to be linked with a safer total recordable injury rate and both indicators included having high percentages of workers employed for more than five years.

The second and third phase of data collection for my dissertation focused on large owner and contractor companies who typically have had a better safety performance in comparison to small contractors. The Delphi method was used to assemble two separate expert panels to quantify the pairwise synergistic effects among thirteen leading indicators from the perspective of an owner and a contractor. The expert panel from the perspective of the owner found the leading indicators with the greatest synergistic impact included pre-task planning, project management team safety process involvement, housekeeping program, owner safety walkthroughs, worker observation process, owner participation in worker orientation sessions, and stop work authority. The other panel from the perspective of a contractor found the indicators with most synergistic impact were pre-task planning, near-miss reporting, worker observation process, an auditing program, and project management team safety process involvement. The results from this study can serve as an aid to all management that are beginning to take a more proactive approach towards measuring and monitoring safety performance.

Dedication

I dedicate this dissertation work to the Alaska Native Science & Engineering Program (ANSEP) students and future students. Your determination, effort, and approach kept me going during this journey.

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Dr. Herb Schroeder has been *Ilisaurri* to me since transferring to the University of Alaska Anchorage (UAA) during my undergraduate degree. It was because of a chance meeting with him that I decided to attend UAA and join the Alaska Native Science & Engineering Program (ANSEP) that he founded in 1995. That was the best decision I have ever made and changed my future. I would not have graduated as an undergraduate or be earning this doctoral degree without ANSEP. Thank you for keeping the vision of ANSEP alive and growing; soon there will thousands of engineers and scientists in this state who are Alaska Native.

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Chapter 1: General Introduction

1.1 Construction Safety

Since the enactment of the Occupational Safety and Health Act (OSH Act) in 1970, the construction industry has had a significant decrease in recordable injuries and fatalities. Those numbers of injuries and fatalities are tracked by the U.S. government's principal fact finder, the Bureau of Labor Statistics (BLS). One annual statistic tracked by the BLS for the construction industry as a whole is the total recordable case (TRC) incidence rate for injuries and illnesses per 100 full-time equivalent workers; this is also referred to as the total case incidence rate (TCIR). According to the BLS data for construction, the TCIR has steadily had a decreasing trend for the years spanning 1989 to the most current data of 2012. This trend is shown in Figure 1.1 (BLS 2012).

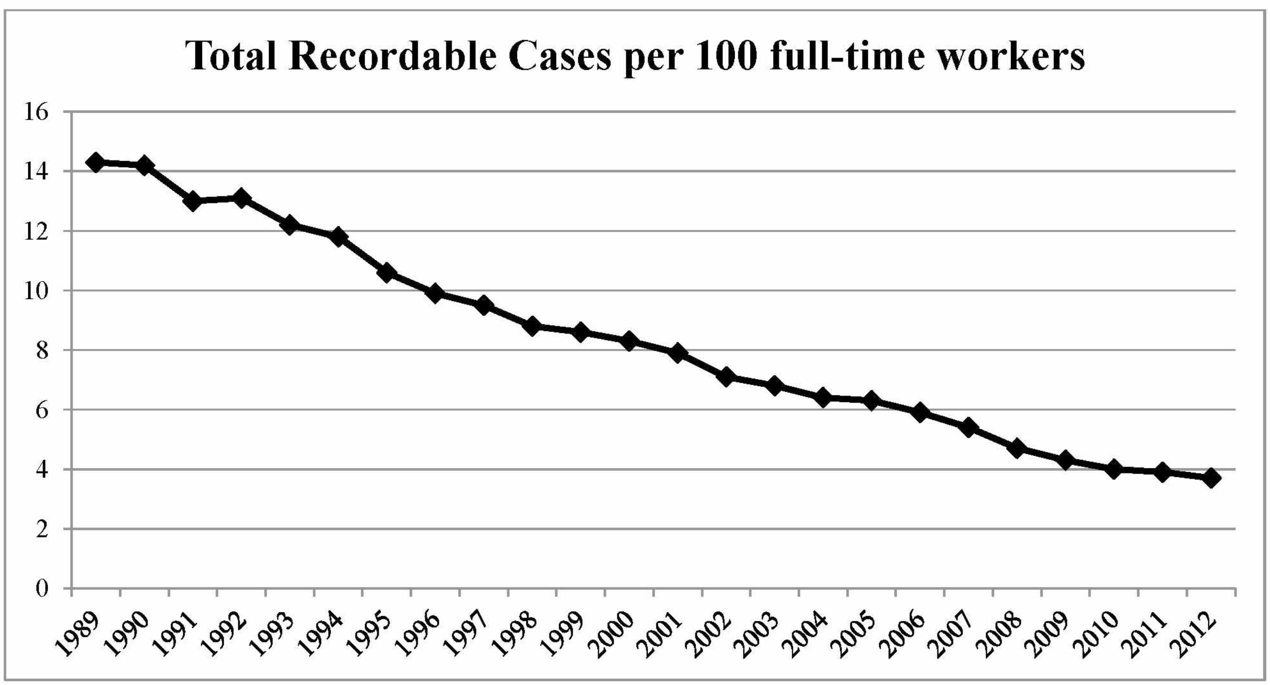

Figure 1.1 Rate of injury and illness per 100 full-time construction workers (1989-2012)

This trend is encouraging for the construction industry; however construction remains one of the most hazardous for workers compared to other industries.

The latest data published by the BLS for 2012 has the construction industry accounting for 775 (17.7%) deaths of the total 4383 fatalities that occurred on the job for all industries (BLS 2012). This is one of the lowest annual fatality counts ever for construction, but the industry still has considerably more than all other major industries. Figure 1.2 compares the construction industry fatalities to other industries (CPWR 2013).

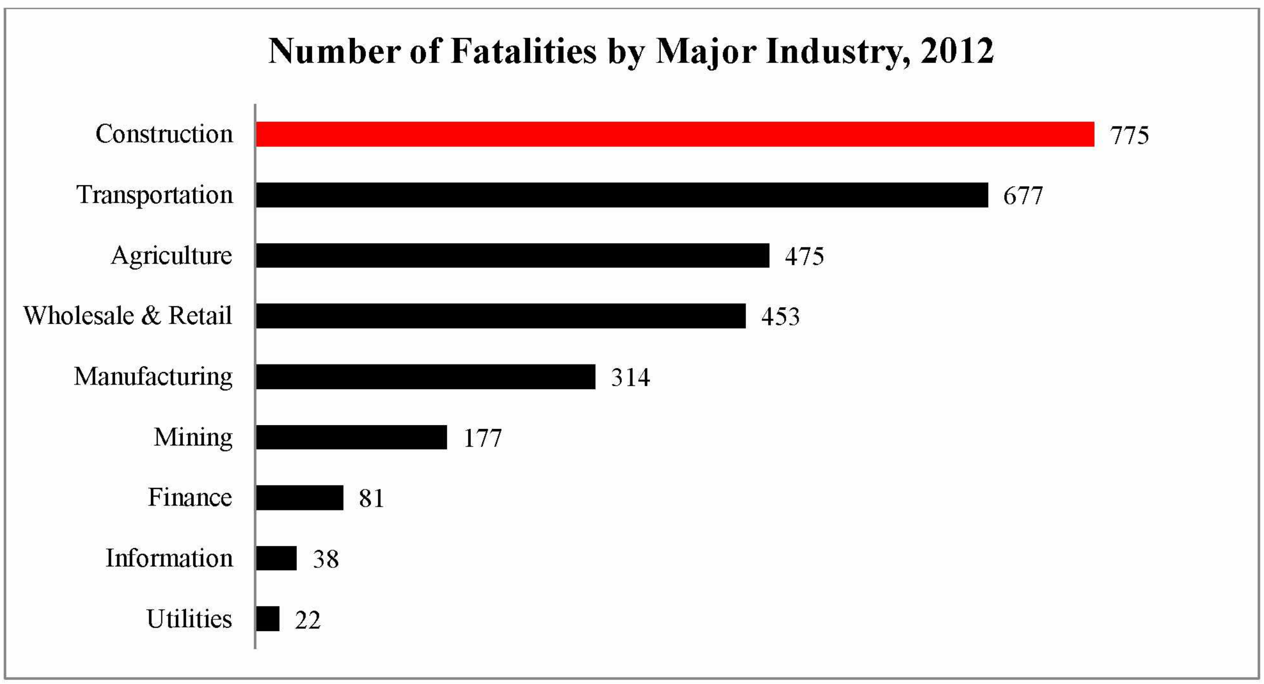

Figure 1.2 Number of fatalities by industry in 2012

However, with the cyclical nature of the construction industry, a better way to view the number of deaths experienced would be to analyze the fatality rate. The fatality rate is typically calculated by the number of fatal occupational injuries per 100,000 full-time equivalent workers and is calculated by Equation 1.1.

$$\left(\frac{N}{EH}\right) X\ 200{,}000{,}000 = \text{Fatality rate, where} \qquad \text{(Equation 1.1)}$$

N= the total number of fatal work injuries

EH = total hours worked by all employees during the year

200,000,000 = base for 100,000 equivalent full-time workers (working 40 hours per week for 50 weeks a year)

Taking the latest data from the BLS on the number of fatalities and total hours worked, the fatality rate can be calculated for each industry and is shown in Figure 1.3 (CPWR 2013).

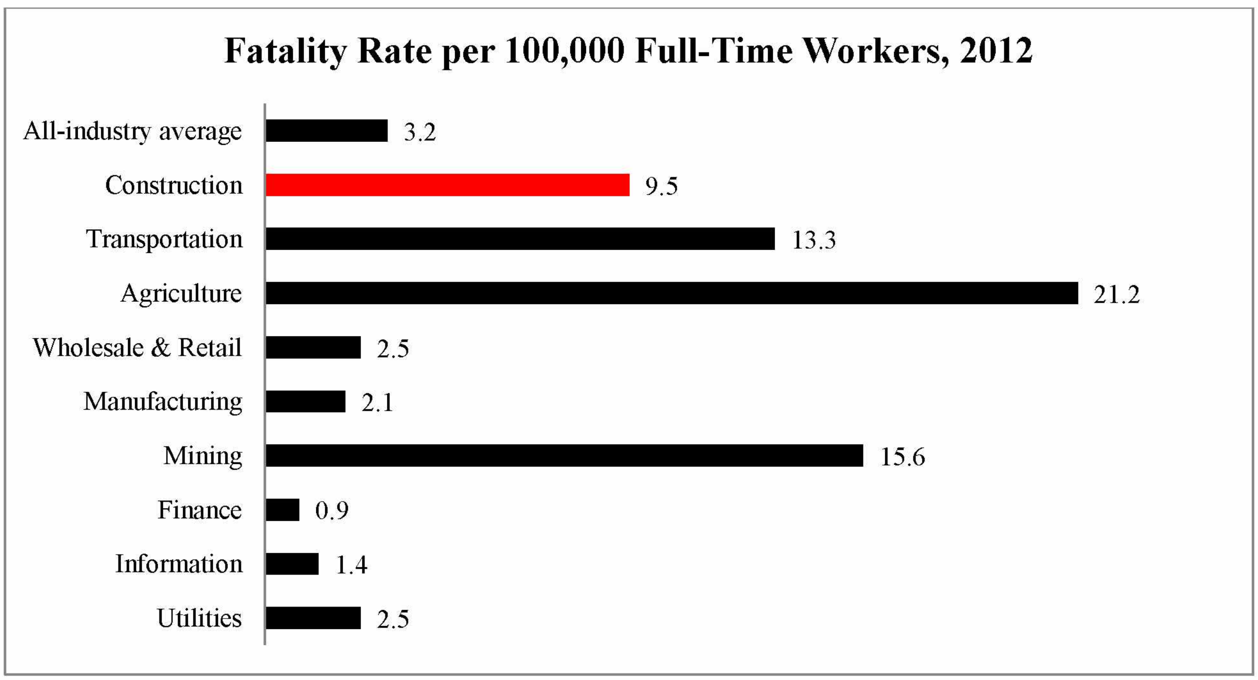

Figure 1.3 Fatality rates by industry in 2012

Figure 1.3 shows that construction is not the most dangerous industry in the U.S., but still accounts for an above average fatality rate. In fact, construction's fatality rate is nearly three times greater than the average rate of 3.2 per 100,000 full-time equivalent workers (FTEs) for all U.S. workers combined. With that being said, the construction industry is improving and the fatality rate has dropped 34% since 1992 (CPWR 2013). Unfortunately though, the current fatality rate in construction has not changed dramatically for the past five years of data (BLS 2012). The construction fatality rate since 1992 to 2012 is shown in Figure 1.4 (BLS 2012).

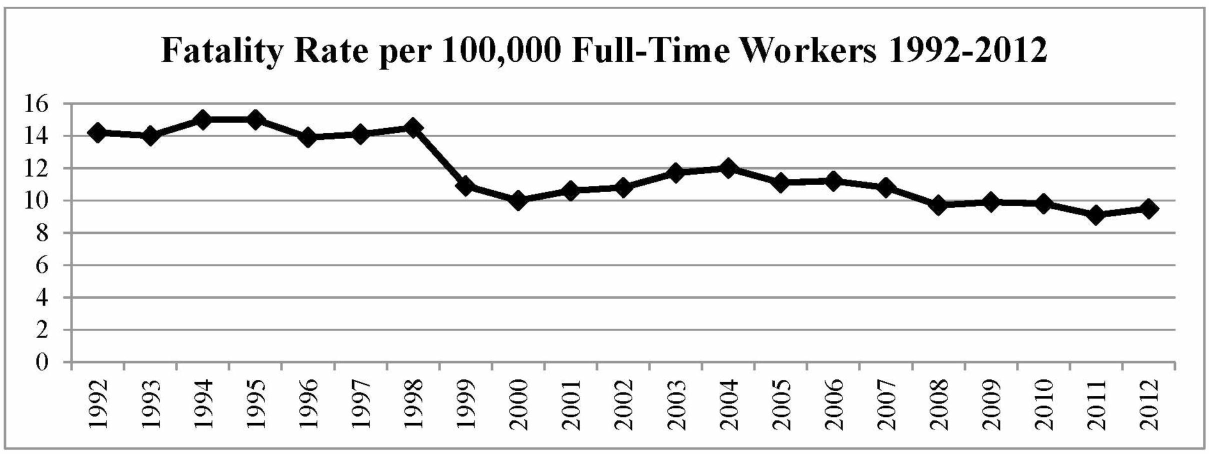

Figure 1.4 Fatality rates in the construction industry (1992-2012)

Interestingly, these fatalities are not spread proportionately across the construction industry when establishment size is taken into account.

The Center for Construction Research and Training (CPWR), formally known as the Center for Protecting Worker's Rights, produces the Construction Chart Book every five years. The Construction Chart Book is the only in-depth publication focusing on the industry in relation to economics and safety. The latest publication uses data up through 2010 that is conducted through restricted access to the BLS data that is only available to a select group of researchers. An interesting finding in the most recent publication is the disproportionate share of fatalities experienced by small establishments compared to large. The relation between establishment size, percentage of workers employed for the establishment size, and the percentage of industry fatalities for each establishment size are shown in Figure 1.5 (CPWR 2013).

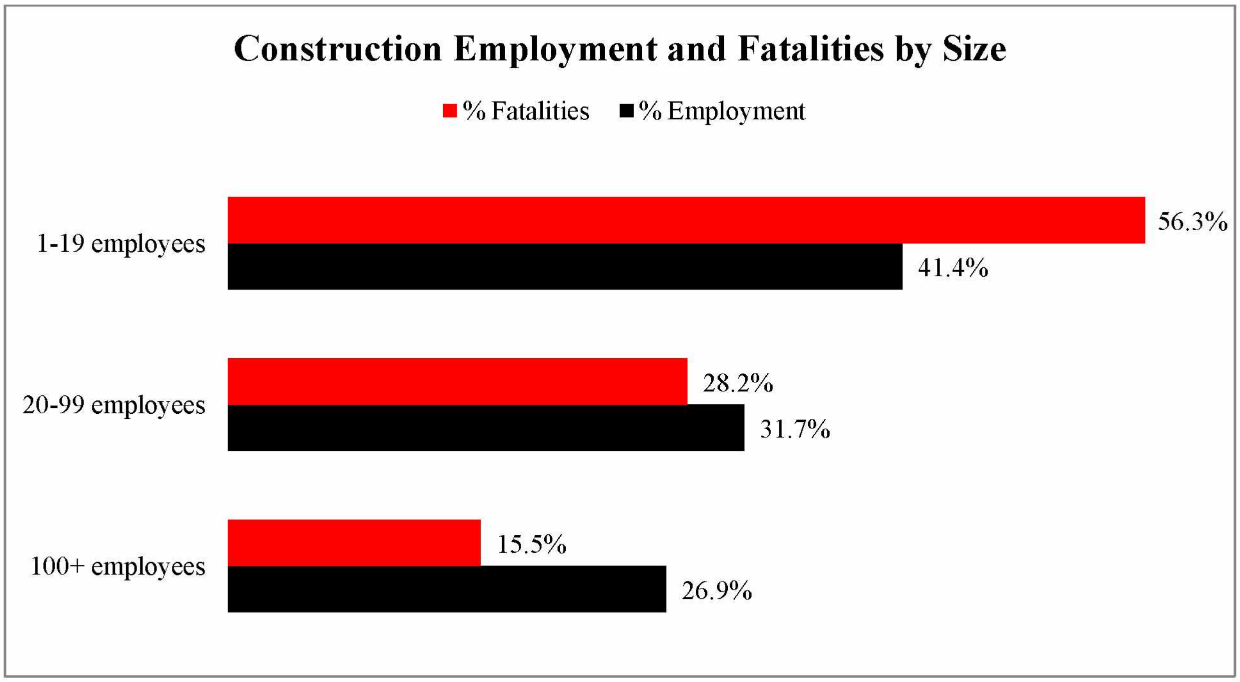

Figure 1.5 Construction employment and fatalities by establishment size (2010)

Figure 1.5 shows that large construction contractors as a whole are experiencing a considerably smaller fatality rate in relation to small contractors. There are several possible reasons for this and some of the characteristics of large contractors with an excellent safety record include having a *zero accident vision (ZAV)* while developing and monitoring safety performance through leading indicators (Hallowell et al. 2013).

1.2 Leading Indicators

The *zero accident vision (ZAV)* began in the early 1990's when the Construction Industry Institute (CII), made up of large contractors, began working towards *'Making Zero Accidents a Reality'* through a number of published reports (CII 1999). Over that time some of the largest multinational construction contractors and owners in the world have reduced their employee and contractor lost time injury rate to nearly zero. Their belief is that all accidents can be prevented; although unachievable initially, this goal is a long term vision for the company. This goal begins at the upper management level and permeates throughout the company to the workers and encourages and promotes the idea that all accidents are preventable. This commitment strategy improves the risk awareness and the safety culture which are critical components of a successful safety management system. To achieve this level of a successful safety management system, there has to be a concentrated internal commitment from the upper management (Findley et al. 2004). The upper management can not only focus on indicators that are assessed after an accident has occurred, but instead also have to look at proactive indicators that can be realized before an incident and if acted upon can prevent the accident.

Safety performance indicators can be proactive or reactive also referred to as leading or lagging. Typically, lagging indicators have been used to evaluate construction safety and are taken after an accident. Examples of lagging indicators include injury and fatality rates, total recordable case rate (TRC), total recordable injury rate (TRIR), experience modification rate (EMR), days away, restrictions or transfer case rate (DART), along with many others. Poor lagging indicators show that there is not an effective safety management system in place for the contractor, but do nothing to eliminate an accident that has already occurred (Coffey 2009). More recently, contractors with a *ZAV* have moved towards accident prevention by using leading indicators to drive their lagging indicators. These leading indicators can be defined as measures of actions, behaviors, and processes that help to make incidents less likely to occur (Blair and O'Toole 2010).

There are two types of leading indicators, passive and active. Passive leading indicators have the ability to predict the potential safety performance of a company; however they are generally unable to affect the work process in the short-term. This is because passive leading indicators require time to improve their threshold value. Examples of passive leading indicators include subcontractor selection and compliance, number of workers on-site that have a 10-hour or 30-hour OSHA card, selection of an insurance carrier, and safety in construction contracts. These passive indicators are strategies implemented before construction begins to establish a commitment towards safety for the project. A recent research study found ten significant passive leading indicators that had a strong negative correlation with project RIR (Baud 2012). Generally, project RIRs decreased by 0.85 per 200,000 worker-hours for every two of the passive indicators implemented. The ten passive proactive metrics are given in Table 1.1 (Baud 2012).

Table 1.1 Ten significant passive leading indicators of safety success (Baud 2012)

Passive Leading Indicator
Owner review and approval of contractor's project safety plan
Participation of all contractors and major subs in safety meetings
Site-specific safety orientation for all managers
100% steel-toed boots policy in place
Medical facilities on-site
First aid log is maintained
Minimum ratio established for safety professionals to workers
Worker-to-worker observation program
Workers involvement in perception surveys
Foremen involvement in policy creation and implementation

On the other hand, active leading indicators affect work processes in the short term through being measured and monitored against threshold values during the project life cycle. Active leading indicators have a greater ability to assist the contractor in achieving zero accidents after the project has started. Examples of active leading indicators include number of safety meetings and what percentage of supervisors are in attendance, percent of negative test results for substance abuse programs, percentage of supervisors and management in attendance at the preconstruction meeting, percentage of skilled workers and foremen familiar with the job-site layout and project management personnel, and number of near misses among others. These active leading indicators have the ability to alert management to a weakening safety process and potentially prevent an accident. From a study funded by the CII, over 100 potential leading indicators were identified and are listed in Appendix A of this dissertation (Baud 2012). Those identified leading indicators were the basis for the first phase of data collection from small contractors. From that same CII study, thirteen were identified as strong predictors of safety performance (Hallowell et al. 2013). Those thirteen leading indicators are given in Table 1.2.

Table 1.2 Leading indicators of predicting future safety performance (Hallowell et al. 2013)

Leading Indicator
Near miss reporting
Project management team safety process involvement
Worker observation process
Stop work authority
Auditing program
Pre-task planning
Housekeeping program
Owner participation in worker orientation sessions
Foremen discussions and feedback meetings with owner's project manager
Owner safety walkthroughs
Pre-task planning for vendor activities
Vendor safety audits
Vendor exit debrief

However, due to resource and time constraints it is highly unlikely that project management will monitor and control all of the leading indicators in Table 1.2. Generally speaking, project staff will implement two to three leading indicators for monitoring (Hinze et al. 2013). One of the results from this study indicates that difficulty in selecting indicators is a barrier to implementation. In an effort to aid in the selection of leading indicators by owners or contractors, the pairwise synergistic impacts were quantified in the second and third phase of this research study.

1.3 Research Study Structure

Researchers have hypothesized that there are synergistic effects when these indicators are combined for measuring and monitoring safety on a construction project (Hinze et al. 2013). However, these effects have not been quantified to date. There are three related phases to my study. The purpose was first to evaluate through phone interviews the use of leading indicators by 25 small contractors that were randomly selected across the U.S. The purpose of the second and third phase was to quantify the synergistic effects among pairs of leading indicators used to predict safety performance on construction projects through a Delphi process. These synergistic effects will be from the perspective of the owner in the second phase and from the perspective of the contractor in the third phase. The hypothesis for the latter phases was that synergy is present between pairs of leading indicators for predicting safety performance. The leading indicators to be analyzed for the latter two phases of this study are presented in Table 1.2 and will be evaluated by construction safety experts using the Delphi method.

1.4 Delphi Method

The Delphi method was developed by a group of researchers within the field of forecasting and planning that were working for the RAND Corporation in the mid 1950's (Dalkey and Helmer 1963). Since that time, the Delphi method has been applied to numerous research areas that have included: transportation, real estate, finance, environmental, health care, academia, and construction. This method has proven useful in these fields when objective data are not feasible, experimental research is impossible, or empirical evidence is deficient (Hallowell and Gambatese 2010). This is also true for construction safety research which has weaknesses. Table 1.3 describes those weaknesses that Hallowell and Gambatese (2010) found specific to construction safety research and how the Delphi addresses each.

Table 1.3 Safety research challenges and Delphi method applicability (Hallowell and Gambatese 2010)

Characteristics of safety research	Applicability of the Delphi method
Archival data is incomplete	Delphi offers an alternative judgment-based method of obtaining highly-reliable data
Experiments are unethical and unrealistic	Delphi typically requires no input of experimental data and relies only on judgment of experts
Incidents exist on a relatively long timeline	The judgments of expert participants utilize years of professional and academic experience
The field of study is complex and involves many confounding factors	The use of judgment from expert panelists allow researchers to separate the effects of desired factors from confounding factors in a properly designed survey
Expert knowledge of the topic required to accurately rate the interrelationship	Delphi is characterized by the use of a prequalified group of experts in an effort to achieve consensus of opinion
Broad topics and number of ratings are outside the scope of one expert	Delphi studies typically involve 8-12 highly qualified individuals that have met a minimum level of expertise
Experts are geographically dispersed and funding for research is limited	Anonymity and the use of e-mail allows any expert with internet access or a mailing address to participate from their location
The impact of research on human welfare may be significant	Delphi is highly-rigorous and preferred over all other judgment-based techniques

1.4.1 Application of the Delphi Method in Construction Engineering and Management Research

Hallowell and Gambatese (2010) identified seven studies that have used the Delphi method for construction research, since that time there have been many more (Arditi and Gunaydin 1999; Del Caño and De la Cruz 2002; De la Cruz and Del Caño 2006; Gunhan and Arditi 2005a,b; Hyun et al. 2008; Robinson 1991). Earlier studies used a variety of implementation methods, resulting in criticism from some researchers. Table 1.4 lists the main criticisms that have been published in the past (Hallowell and Gambatese 2010).

Table 1.4 Delphi method criticisms (Hallowell and Gambatese 2010)

Delphi method criticisms
Differing requirements of what an “expert” is
Appropriate methods for data collection were not selected
Differing strategies with feedback that occurs with the expert panel
Number of rounds completed
Inconsistent consensus measures

Prior to applying the Delphi method to my study, a detailed literature review was completed to avoid these variations that have resulted in criticism of the Delphi method in the past. Through that review, an article was found by Hallowell and Gambatese (2010) who suggested a procedure for conducting a Delphi study when conducting construction research. This recommended procedure for effective Delphi studies is given in Figure1.6 from Hallowell and Gambatese (2010).

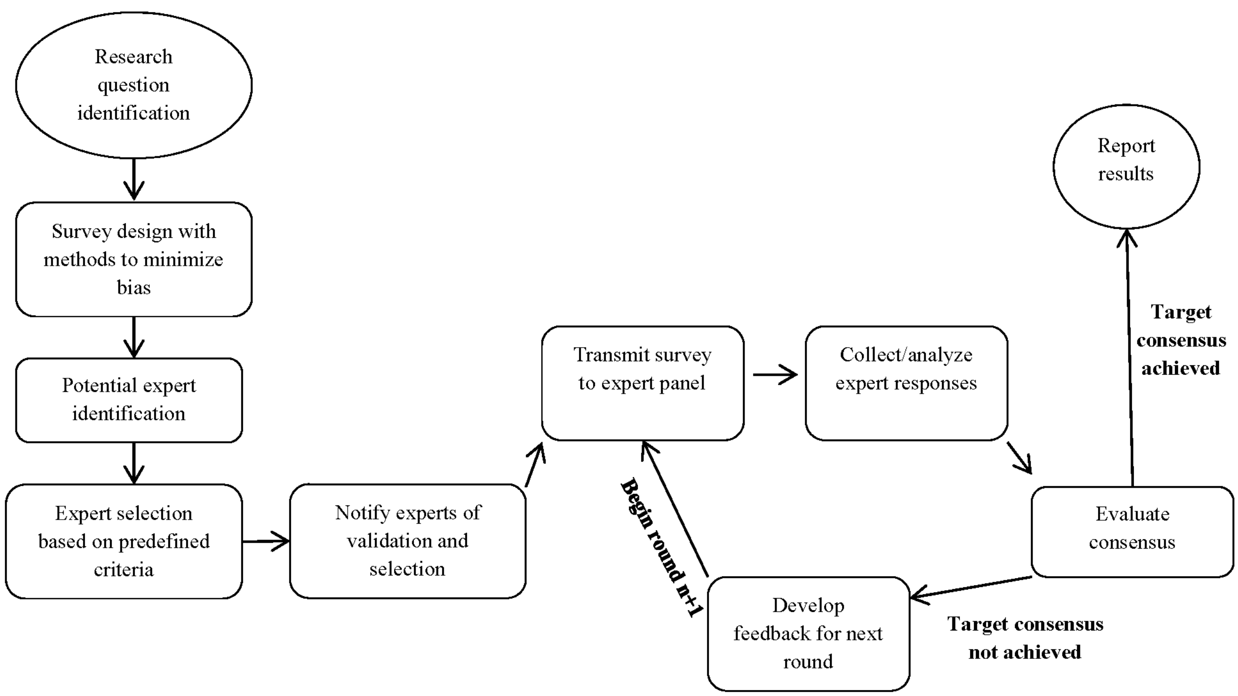

Figure 1.6 Suggested Delphi process (Hallowell and Gambatese 2010)

The purpose of the Delphi method is to extract unbiased information that deals with complex problems on uncertain issues (Linstone and Turoff 1975). The unbiased information is gathered from a formalized method of communication that is characteristic of anonymity, iteration with controlled feedback, and statistical response around a panel of independent experts to gain a reliable consensus (Dickey and Watts 1978). The following subsections will discuss the characteristics of the Delphi method followed by the research design for the Delphi portion of this study.

1.4.2 Anonymity

During a Delphi study all experts maintain their anonymity from the other participants (Linstone and Turoff 1975). The purpose of anonymity is to prevent a dominating effect that some participants may exhibit as a personality trait or through authority. For example, if anonymity is not followed, a well-known and respected safety engineer may use his or her authority in the field of safety to influence other panelist responses or others may not want to disagree with that person. As a result, anonymity will allow the experts to express their opinions freely, while encouraging an open forum for all to hear and consider (Dickey and Watts 1978).

1.4.3 Iteration with Controlled Feedback

According to Linstone and Turoff (1975), the Delphi method consists of several iterations of surveys that are also referred to as rounds. The purpose of the iterations with controlled feedback is to inform the experts about the opinion of the other participants while keeping everyone anonymous. Through these rounds, the experts are able to change their opinion or provide justification as to why they differ from the group. During this process, the facilitator aims to bring the group to consensus (Dickey and Watts 1978). Measuring consensus is one of the most contentious areas of the Delphi method and standards for measurement have not been agreed upon; however the most common are measures of central tendency.

1.4.4 Statistical Response

Statistical response can be presented to the expert panel in a number of ways. The purpose of the statistical response is to aggregate the responses and compare each individual response to the group. This individual feedback is presented to the expert in subsequent rounds along with any reasons why experts deviate from the group. Past research studies have used statistical measures that have included reporting the mean, median, or mode to the experts (Dickey and Watts 1978). According to Hallowell and Gambatese (2010), a difficult aspect of the research design for the Delphi method is selecting how this statistical response will be aggregated.

1.4.5 Delphi Research Design

The Delphi method has been criticized by some due to the short-cuts and modifications to the prescribed research method (Sackman 1974; Armstrong 1978). To avoid that criticism for this study, the following sections present how the research design for this study is modeled after specific guidelines developed by Hallowell and Gambatese (2010) for construction safety research. These specific guidelines developed by Hallowell and Gambatese (2010) include the following headings that will be discussed in the next subsections: expert requirements, number of panelists, number of rounds and feedback provided, and the format of the Delphi rounds.

1.4.5.1 Expert Requirements

In order to be considered a Delphi study the panelists must be qualified as experts using objective criteria prior to initiating the first round of data collection. As is customary, the demographic data that was used to qualify individuals as experts was obtained during an introductory survey. Rogers and Lopez (2002) suggest that each expert panelist meet two of the following categories given in Table 1.5.

Table 1.5 Expert qualification categories from Rogers and Lopez (2002)

Delphi panelist qualification
Author of an article, chapter, or book
Conference presenter
Member or chair of a relevant committee
Five years of employment in the industry
Faculty member with relevant research

In another study, Veltri (1985) suggests a more subjective selection process that requires the participants to meet four requirements that are given in Table 1.6.

Table 1.6 Expert qualification categories from Veltri (1985)

Delphi panelist qualification
Quality performance record in the research area
Ability to devote the time necessary for the study
Holds a level of objectivity within the field
Has the time and energy to fully dedicate to the research

According to Hallowell and Gambatese (2010), the subjective nature of these guidelines will qualify many participants, but the validity of the results may be given up.

Rajendran and Gamabatese (2009) and Hallowell and Gambatese (2010) created a more stringent procedure in selecting experts to enhance the validity of the results. This procedure required every panelist to meet at least four of the following eight characteristics related to construction safety management in order to qualify as an expert. These characteristics are listed in Table 1.7 (Hallowell and Gambatese 2010).

Table 1.7 Expert qualification categories from Hallowell and Gambatese (2010)

Delphi panelist qualification
At least three peer reviewed journal articles on construction safety
Presenter on safety related topic at a conference
Member of a construction safety committee
Five or more years' experience in construction with safety management
Faculty member with a research focus in construction safety
Author or editor of a book or chapter in construction safety
B.S. or higher in a field relevant to construction safety
Professional designation
Professional Engineer
Certified Safety Professional
Associated Risk Manager
Licensed Registered Architect

Hallowell and Gambatese (2010) also realized that sometimes a topic of knowledge does not warrant academic experience and may be inappropriate for the study. In that event a flexible point system has been developed by Hallowell and Gambatese (2010) and is given in Table 1.8.

Table 1.8 Delphi expert panelist point system

Experience	Points (each)
Professional registration	3
Years of professional experience	1
Conference presentation	0.5
Committee member	1
Committee chair	3
Peer-reviewed journal article	2
Faculty member	3
Writer/editor of a book	4
Writer of a book chapter	2
BS	4
MS	2
Ph.D.	4

Hallowell and Gambatese (2010) advocate for a panelist to be qualified as an expert, four categories should score at least one point. It is also noted that depending on the research study, these categories and points may need to be modified for what is being studied.

My study modified these categories to select potential experts in the industry that have experience using safety leading indicators on construction projects. These experts have been selected from contractor and owner companies and have worked on larger projects with excellent safety records where safety performance was measured and monitored with leading indicators. It is expected that these indicators will increase in use as the industry as a whole begins to adopt the *ZAV*. The flexible point system for qualifying experts chosen for this study is given in Table 1.9.

Table 1.9 Proposed Delphi expert panel qualification categories

Experience	Points (each)
Professional registration	3
Years of professional experience (1 point per year)	1
Years of construction safety management (1 point per year)	1
Years using proactive metrics for safety (1 point per year)	1
Conference presentation	0.5
Committee member	1
Committee chair	3
BS	4
MS	2
Ph.D.	4

The potential panelist will need to score at least ten points to be considered an expert while also having experience using construction safety leading indicators.

1.4.5.2 Number of Panelists

Delphi panels have ranged from eighty expert members to as small as three. Brockhoff (1975) and Boje and Murnighan (1982) looked into the impact that the number of panelists had on the level of accuracy of the Delphi method. Those studies found that the appropriate number of panelists for the typical Delphi study ranges from eight to fifteen for the most accurate results. This recommendation overlaps Hallowell and Gambatese's suggestion of eight to twelve experts for an effective Delphi study (Hallowell and Gambatese 2010). This study followed those recommendations by having two separate panels of eight qualified experts that consisted of construction contractor safety managers, upper-level management, and representatives of owner companies.

1.4.5.3 Number of Rounds and Feedback Provided

The Delphi method is characterized in part by the use of multiple rounds while providing controlled feedback. Most literature suggests that the Delphi process should continue for as many rounds as it takes to achieve the desired consensus. However, other literature reveals that Delphi results are most accurate after rounds two and three and become less accurate with additional rounds (Dalkey 1972). Hallowell and Gambatese (2010) suggest three rounds because this tends to be adequate for achieving consensus and implementing the controls to minimize bias. The second and third phase of this research study conducted three rounds of surveys with detailed feedback provided at the beginning of rounds two and three.

Providing adequate and strategic feedback allows expert panelists to evaluate the opinions of other members anonymously without being subjected to time consuming discussions. To ensure adequate feedback that would promote consensus, my study involved controlled feedback at the beginning of Rounds 2 and 3. In Round 2 the median ratings from the previous round were provided to all panelists in addition to their personal rating from the previous round. During Round 2, panelists were asked to provide reasons if they believed that the true value for a particular rating deviated more than 10 percent from the group median from Round 1. In Round 3 the panelists were provided with the median ratings from Round 2, their personal rating from Round 2, and the reasons provided by all panelists for outlying responses. At that point the panelists were given the option to change their ratings or give a reason as to why they are outside of the range of group medians.

For the second and third phase of this research study, the experts gave ratings of the percent increases in effectiveness for predicting safety performance when pairs of leading indicators are measured together on a construction project. These percent increases were quantified in ranges rather than point estimates, and, for convenience, the ranges were determined to be in ten percent increments from zero to one hundred percent. The goal of phase two and three of this study was to gain an overall consensus within one range also meaning within ten percent deviation for all of the ratings. The consensus for this study was calculated by first determining the group's median, followed by finding the average of all of the expert's absolute deviation from the median for each rating. With 13 leading indicators, there were a total of 78 ratings. This was followed by taking the average of all of the average absolute deviations for all 78 ratings. Consensus was reached when the average of the average absolute deviations was ten percent or lower.

The absolute deviation was used as a statistical measure over standard deviation. By selecting the absolute deviation, the variability of the response was about the median rather than the mean. The purpose of selecting the median was to minimize the effect of biased responses and outliers while being a more reliable statistical measure when utilizing the Delphi method (Hallowell and Gambatese 2010). The experts' ratings and the median of the group were used to find the absolute deviation, which was the absolute difference between the group median and each expert's individual rating.

1.4.5.4 Format of Delphi Rounds

The Delphi portion of the study was conducted over a three month period with approximately two weeks dedicated to each survey round. Before the Delphi rounds began, a four page questionnaire was given to anyone that agreed to participate for the purpose of qualifying them as experts. The intention of the introductory survey was to identify the potential participants professional information related to safety and health in the construction industry and their use of leading indicators on projects. The introductory survey has been included as Appendix B at the end of this dissertation.

The length of each Delphi round consisted of approximately two weeks in duration for the response with one week allotted afterwards to compile the results and create new individualized surveys for each expert. A two-week response time was necessary because of the amount of ratings each panelist was asked to provide. Once the surveys were created they were emailed to all qualified experts unless an expert preferred a hard copy. An example of a Round 1 survey has been included in Appendix C.

As indicated previously in this chapter, one of the characteristics of the Delphi panel is statistical response and feedback. The statistical response and feedback for this study included the participants' previous ratings, along with the group median for each pair-wise rating. The statistical response was aggregated after Round 1 and presented in the individualized survey for Round 2. This was done after Round 2 and in the event the participant deviated from the median by 10 percent above or below the median, they were asked to provide justification for their outlying response. These responses were also presented in Round 3 for all the participants to consider. This justification for outlying responses was also asked in Round 3. The final results from Round 3 were also aggregated, but not presented to the participants since the study had concluded. An example of how the statistical response appeared on the survey for the panelists in Round 2 is included as Appendix D at the end of this dissertation. Finally, an example of how the statistical response and written feedback on a Round 3 survey is included as Appendix E of this dissertation.

The following chapters will include individual manuscripts from distinct portions of my research study. The first manuscript in the next chapter will condense the results from a telephone interview study of 25 small contractors about their use of leading indicators. The manuscript in the third chapter quantifies the synergistic effects among leading indicators of construction safety from the perspective of an owner. The manuscript in the fourth chapter also quantifies the synergistic effects among leading indicators, but from the perspective of a contractor. Lastly, the general conclusions and recommendations tie the findings from the three studies together.

Chapter 2: Feasibility Study for Discovering Safety Strategies of Small Contractors[1]

2.1 Abstract

Construction safety research has traditionally considered only large contractors even though the majority of firms in the industry are small and medium sized establishments. Moreover, small contractors experience a disproportionately high fatality rate in comparison to other establishment sizes. This metric can be described as a lagging indicator focusing on the number of fatalities an establishment experiences per 100,000 full-time equivalent workers. Alternatively, leading indicators are measures of the safety process and can initiate an action to prevent an incident from occurring. This study conducted telephone interviews with 25 randomly selected small contractors in the United States to (1) identify and describe the safety strategies implemented in their firm, and (2) discuss the specific challenges that small contractors must overcome to employ these strategies. The results were then analyzed to find the total percentages of each strategy that are used among the firms and their relationship to the company's total recordable injury rate (TRIR). In all, 46 strategies were found to be in use by at least one contractor and two were found to be linked to lower TRIRs. The study also reveals that additional research in cost-effective strategies is needed for all small contractors who have been widely neglected within academic research in the past 40 years.

CE Database subject headings: Construction management; Safety; Accidents; Fatalities.

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2.2 Introduction

The construction industry has traditionally had a high rate of work-related injuries and fatalities in comparison to other industries. While these rates have decreased considerably since 1970 when the Occupational Safety and Health (OSH) Act was enacted, the construction industry still accounts for a fatality rate that is approximately three times the all-industry average and remains nearly unchanged from a decade ago (BLS 2012). Furthermore, within the construction industry, establishments with less than 20 workers accounted for 56% of the construction deaths last year, while only employing 41% of the wage and salary workforce. (CPWR 2013). However, this disparity is not observed with nonfatal injury rates and the Center for Construction Research and Training (CPWR) states in their most recent Construction Chart Book that small contractors are especially underreporting accidents. As a result, the National Institute for Occupational Safety and Health (NIOSH) has identified small contractor safety management as a key research objective.

Construction safety programs encompass numerous injury prevention strategies. A number of research studies have documented these strategies and some studies have also determined the strategy's relative effectiveness. For companies with large safety budgets, a comprehensive safety program can institute many of these strategies, but this raises a problem for small contractors. Since small contractors operate on a limited safety and health budget, they only have the ability to put into practice a small subset of strategies as part of their construction safety program. In addition, these strategies are selected based on intuition and peer suggestion (Hallowell and Gambatese 2007). These limited construction safety programs can consist of techniques, strategies, initiatives, plans, and indicators all with the goal of improving safety performance (Jaselskis et al. 1996). Recently, as companies focus their efforts on achieving zero accidents, leading indicator research has become an important topic. This is mainly due to the fact that, while lagging indicators are useful for evaluating the effectiveness of a safety program, they don't prevent the initial incident from occurring. In contrast, leading indicators have the ability to be predictors of safety performance.

Leading indicators are defined as the measures of attitudes, behaviors, practices, or conditions that influence construction safety performance (Toellner 2001). Many leading indicators have been identified and studied within the context of large contractors in recent years. However, no attention has been paid to identifying which leading indicators apply within the domain of small contractors. To address this gap in the knowledge base, twenty-five small contractors that employed two to nine workers were randomly selected and were first asked to identify and describe their use of safety leading indicators previously identified by researchers. This step was followed by finding the specific barriers to implementation when the indicators were found not to be in use. Investigating the usage and barriers of leading indicators by small contractors will give insight into how these strategies need to be modified for broader implementation.

2.3 Literature Review

One of the National Occupational Research Agenda (NORA) construction sector goals developed by the NIOSH explicitly states the need for researchers to team up with small contractors. The purpose of this small contractor research is to identify the best practices for safety and health management and disseminate the information to other small employers. Despite this research priority and the current disproportionate fatality rate, few studies have focused on safety strategies for small construction firms. In one of the few studies, McVittie et al. (1997) found that as firm size decreases, the injury rate increases due to the lack of resources, less union labor, and fewer government (e.g., OSHA) inspections. Similar findings have been reported in other industries such as logging (Mason 1977), transportation (Moses 1994), and manufacturing (Sust 1971). In addition, following the OSH Act of 1970, injury rates have declined at a slower rate for small contractors while fatality rates have been consistently higher for these same firms (CPWR 2013). These poor safety performance trends give reason to conclude that the initiatives and research performed since the OSH Act have affected small construction firms to a lesser extent.

The construction industry uses a variety of indicators to monitor safety performance regardless of the size of the contractor. Traditionally, safety performance has been assessed by metrics such as the Occupational Safety and Health Administration (OSHA) total recordable injury rate (TRIR); the days away, restricted work, or transfer (DART) injury rate; or the experience modification rating (EMR). These measures are lagging indicators because they are linked to the outcomes of past events. While lagging measurements reveal the effectiveness of a firm's safety program and potentially help gain awareness towards preventing the reoccurrence of negative outcomes, these reactive measures do not prevent the incident that has already occurred. As a result, the industry as a whole will never achieve the "zero accident goal" by strictly focusing on lagging indicators. Instead, contractors and owners need to shift their efforts to also include proactive indicators that can prevent an accident by alerting workers and management to developing safety problems at their respective construction projects. Proactive metrics are also called leading indicators.

Leading indicators are measures that can be used as predictors of future levels of safety performance because they reflect information on the safety process (Hallowell et al. 2013). Leading indicators consist of a set of selected measures that describe the level of effectiveness of the safety process and are linked to actions taken to prevent accidents (Kaplan and Norton 1992). Leading indicators may include conditions, events, strategies, or other measures that precede an incident and have a predictive value in regards to unsafe conditions or behaviors. The relationship between leading and lagging indicators is illustrated in Figure 2.1 (Harding 2010).

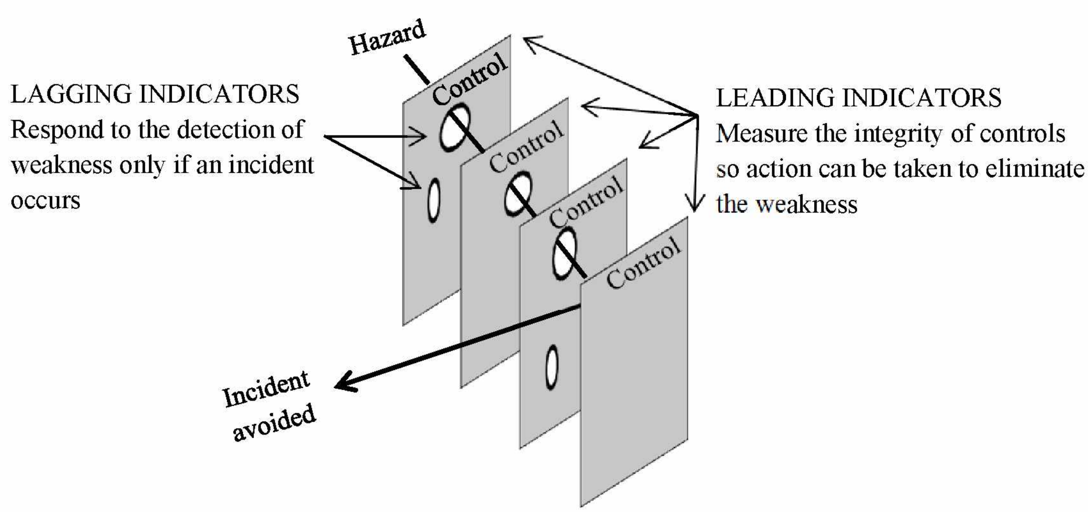

Figure 2.1 Relationship between Leading and Lagging Indicators (Harding 2010)

There are two types of leading indicators, passive and active. Passive leading indicators have the ability to predict the potential safety performance of a firm; however they are unable to generally affect the work process in the short-term. This is due to passive leading indicators having a time frame that generally takes longer to influence. Examples of passive leading indicators can include subcontractor selection and compliance, number of workers on-site that have a 10 or 30-hour OSHA card, selection of an insurance carrier, and safety in construction contracts to name a few. On the other hand, active leading indicators have the ability to affect a work process in the short term while being measured or controlled throughout the project lifecycle. A few examples of active leading indicators include the number of safety meetings and what percentage of supervisors are in attendance, the percent of negative test results for substance abuse programs, or the percentage of supervisors and management in attendance at the preconstruction meeting.

In the past five years, the Construction Industry Institute (CII) has funded a research effort on safety leading indicators. The result of this effort has proven to be effective for larger contractors. From that research, a set of leading indicators have been connected to exceptional safety performances by large contractors (Hallowell et al. 2013). It is hypothesized that small contractors also implement some of these strategies. By finding what strategies small contractors use and what the barriers are when they do not, researchers can begin to understand the safety management of these firms.

2.4 Point of Departure

Small contractors have been found to be at a higher risk than larger firms for experiencing a fatality according to data from the Bureau of Labor Statistics (BLS) and the CPWR. In the past, research studies have not focused on small contractor safety management and unfortunately the fatality disparity trend has continued. The purpose of this research study is to find what leading indicators are being used by small contractors and what the barriers are when they are not in use. Interviews were conducted with twenty-five small contractors. A knowledgeable individual within each company was asked to identify and describe the safety strategies they use and discuss the specific challenges that small contractors must overcome to employ these strategies.

2.5 Research Methods

To accomplish the research objectives, telephone interviews were conducted with twenty-five randomly selected small contractors in the United States. The objective of the interviews was to quantify the rate of implementation of different safety strategies (i.e., leading indicators) and identify the barriers to implementation. Previous research has identified leading indicators that have been used by large contractors with exceptional safety records (Baud 2012). These previously identified leading indicators were the basis for exploring the rate of implementation among the small contractors interviewed.

The contractors were randomly selected through a sampling method devised by the author due to there not being an extensive list of small contractors in the US. At the time of data collection, the latest CPWR Construction Chart Book (2013) indicated there were 884,300 construction establishments in the U.S. and 79% employed fewer than 10 workers (698,597). To sample from that population, an online phone number database service named Switchboard.com was used to identify potential participants. Switchboard.com is the leading provider of online yellow pages and focuses on listing small and medium size businesses. In addition, the service uses the SuperMedia multi-platform technology that combines ten other phone listing services to ensure a complete directory. It should be noted that all companies have voluntarily provided their contact information to these services in return for being listed in the directory. Prior to data collection, the research team performed a search using construction-related keywords such as ('contractor' and 'builder') and identified 310,021 firms through the platform. The firms that would not be represented within this population would most likely include sole proprietors, contractors with unique services that would not include typical construction keywords, and/or businesses that do not wish to have their contact information divulged to the public. Thus, the research team believes that the pool of approximately 300,000 construction firms is representative of small contractors in the construction industry. The research team used Microsoft (MS) Excel to randomly sample from this pool and focused on interviewing employers with less than ten but greater than one employee.

All interviews were conducted over the phone with a knowledgeable representative of the company. An individual was considered knowledgeable if they were aware of the safety strategies implemented by the firm. For these small firms, this individual was often the owner or foreman. These interviews lasted 30 to 45 minutes over the phone and sometimes required a call back. During the interview the company demographics were collected first, followed by the leading indicator portion that consisted of yes or no questions. If the response was no, the interviewee was asked to elaborate on the barriers to implementation. While if the response was yes, the interviewee was asked to describe how the indicator was implemented. The interviewees were instructed that the questions were rapid fire due to the extensive list of the leading indicators being studied. To keep a standardized interview protocol, a template was created within MS Excel to ensure consistency and reliability. In some cases the interviewee was unable to answer questions resulting in a follow-up call, although in some instances the questions remained unanswered.

2.6 Results

The study was designed to analyze the implementation of different safety strategies by 25 small contractors. From the previous CII study that identified 93 leading indicator safety strategies, 50 pertained directly to contractors as opposed to owners or vendors (Baud 2012). Of the 50, 46 were found to being utilized at some rate by the 25 randomly selected U.S. small contractors. To find the 25 contractors that met the small employer definition and were willing to be interviewed, over 1000 phone calls were made for a response rate around two percent. Each call was initiated with a brief introduction about the researcher and the nature of the study. During the interview each contractor was asked to identify and describe their use of the safety leading indicators. The contractors were also asked to discuss the specific challenges that must be overcome when the indicator was found to not be in use. Before those questions were answered, demographic data were gathered that included: number of employees, construction service, industry sector participation, and the company TRIR. The majority of the firms were involved in building construction for residential and commercial. The summary of the company demographics and their rate of leading indicator implementation are provided in Table 2.1.

Table 2.1 Small Contractor Demographics

Location	# of Employees	# of Leading Indicators	TRIR
TX	2	7	1
CA	4	7	1.5
CA	2	10	0
AL	3	11	2.5
CT	4	13	2
CO	6	14	2.7
NM	4	16	2.7
LA	5	16	3
AZ	7	18	2.3
VA	5	18	3.6
UT	5	18	5.6
NC	6	19	3.4
MI	3	19	4.6
IA	5	19	5.6
NY	8	19	6.7
FL	4	19	8
CO	8	21	1.8
CA	5	22	7.8
NJ	7	27	4.3
CO	4	28	3.6
WI	8	28	6.7
TX	7	29	4.2
NV	7	30	4.5
NY	6	31	4.9
NY	9	34	4.3

After the demographic data were collected, the interview began with asking the contractor if they implemented each of the leading indicators that were identified for this study. A handful of these indicators were found to be commonly used among the firms. Specifically, eight of the leading indicators were utilized by 75% or more of the small contractors. These can be regarded as common practices among the small contractors interviewed. Further research into these strategies will reveal if these are widely accepted among other small contractor safety programs in the construction industry. These core practices and their rate of implementation are presented in Table 2.2.

Table 2.2 Commonly Practiced Safety Leading Indicators

Safety Leading Indicator Implemented	% of Use
First-aid kit on-site	100
Safety meeting before project	92
Owner signed project safety plans	88
100% steel-toed boots policy	88
25% or more of workers employed for 5+ years	88
Company designated safety instructor	84
New employee background check	84
Required safety training for workers	76

The remaining leading indicators with some rate of implementation under 75% among the small contractors included 38 strategies. These are shown in Table 2.3.

Table 2.3 Safety Leading Indicator's Implementation Rate

Safety Leading Indicator Implemented	% of Use
Foreman as safety representative	72%
Company specific new hire training	72%
Owner at safety meeting before project	68%
Worker involvement in accident investigations	68%
50% or more of workers employed for 5+ years	68%
Required test after training	64%
Safety training maintained for workers	60%
Management review craft training	60%
Injury reporting and analysis program	56%
Zero tolerance for safety non-compliance	52%
Owner signed OH&S manual	48%
Safety meeting at least weekly	48%
First-aid log	48%
100% of workers with English as first language	48%
Worker-to-worker observation program	44%
JHA program	40%
Formal on-site restroom quality policy	36%
Foremen involved in policy creation and implementation	36%
50% or more of workers with OSHA 10-hr	32%
Daily safety meeting	32%
Foremen involvement in safety committees	32%
75% or more of workers employed for 5+ years	28%
Safety leadership training for foreman	20%
100% of workers with OSHA 10-hr	16%
Regularly scheduled equipment inspections	16%
Formal lessons learned management program	12%
Worker involvement in safety perception surveys	12%
100% of workers employed for 5+ years	12%
Worker incentive for no injury	12%
Managers/foreman take project specific training	8%
100% earplug policy	8%
100% reflective vest policy	8%
Established disciplinary program	8%
Root cause analysis program	8%
Leadership development program for foremen	8%
Foremen complete safety perception surveys	8%
Safety supervisors to worker ratio	4%
First-aid station on-site	4%

The bottom third of Table 2.3 only have one to four small contractors that implemented these strategies. Before discounting these strategies, more research among other small contractors needs to be investigated to find if their use is more widespread.

The remaining safety leading indicators strategies that were found not to be in use by the small contractors included: company work hour restrictions, noise measurement and mitigation program, and a full-time safety manager. It is interesting to note that 19 companies stated that they had a full-time safety manager in the interview, but on further investigation it was found that in all cases the safety manager had another role which included foreman or owner of the company. Finally, one leading indicator dealing with safety training was dropped in the interview due to redundancy.

In the event of a no response, the interviewee was asked to provide at least one reason as to what the barrier of implementation was. Many reasons were collected from the small contractors and the most common response was that the strategy was unnecessary for their firm. Other common responses included the firm was too small, not enough time, a perception of the strategy being ineffective, and cost, which are shown in Table 2.4.

Table 2.4 Small Contractor Barriers to Safety Leading Indicator Implementation

Barrier	Frequency of Response	Percent Distribution
Unnecessary	107	30.1%
Too small of company	53	14.9%
Not enough time	39	11.0%
Not effective perception	37	10.4%
Cost	32	9.0%
Only if contract requires	21	5.9%
Not required	18	5.1%
Unfamiliar	15	4.2%
Foreman's duties	13	3.7%
Language barrier	7	2.0%
Family business	4	1.1%
Owner discretion	3	0.8%
Equipment rented	3	0.8%
Not considered	2	0.6%
Too formal	1	0.3%
Transient workers	1	0.3%

The barriers of "unnecessary" and "too small of a company" were the top two responses and combined together nearly account for half of the responses given. These responses are informative and show that small contractors need more focus with research that applies specifically to them. Other responses that could potentially indicate a lack of commitment towards common safety strategies include "not enough time" and "only if the contract requires". However it is completely plausible that many of these strategies are better suited for large contractors that have more resources. Regardless of their level of commitment, it is obvious that cost-effective strategies specific to small contractors needs more study, development, and dissemination in the future to help improve the safety record of the construction industry.

2.7 Analysis

Once the level and quality of leading indicator implementation was determined a series of two-sample tests was performed with the software Statistical Package for the Social Sciences (SPSS).

The purpose of the test was to compare the TRIRs for the companies that did employ a specific leading indicator to those that did not to test the null hypothesis of equal medians. Since the TRIRs did not follow a normal distribution, a one-sided Wilcoxon rank sum test (also called the Mann-Whitney) was used to compare the sample mean rank between the groups that used a strategy compared to the group that did not with a 95% confidence interval. The analysis showed two of the 46 safety leading indicators exhibited a strong link (p-value < 0.05) to an improved TRIR. Specifically, seven of the small contractor firms had 75 percent or more of their workers employed for more than five years and had a mean difference of 2.67 lower TRIR than the group that did not. Three of these contractors also employed 100 percent of their workers for more than five years and had a mean difference of 0.26 lower TRIR than the group that did not. These two strategies are shown in Table 2.5.

Table 2.5 Leading Indicators Strongly Linked with Lower TRIRs

Leading Indicator	Difference in Mean	# of Firms Implementing	P-value
75% or more of workers employed for 5+ years	2.67	7	0.001
100% of workers employed for 5+ years	0.26	3	0.001

There have been similar findings from other studies that have looked at worker age to see if there is any correlation to having more accidents. It has been documented that older, more experienced workers have fewer accidents than young workers (Salminen 2004; Kossoris 1948). However, that finding does not necessarily validate the leading indicator of “percentage of workers at the firm for five or more years”. The findings imply that minimizing worker turnover has the potential to improve future contractor safety performance.

2.8 Study Limitations

Although the results were found using a novel data collection technique, there are some limitations. First, the basis for the statistical analysis was dependent upon self-reporting of the company TRIRs, which ranged from 0.0 to 8.0. Although the companies were assured that their identity would be kept confidential, it is possible that an interviewee may have felt uneasy with divulging their TRIR over the phone. Secondly, the number of interviews conducted was small in comparison to the entire industry of small contractors in the U.S. Thus, any exaggeration of safety records will have obvious consequences to the findings. Nonetheless, the results are an important contribution since there is presently little research that has evaluated the safety of these firms who have been found to have the highest fatality rate while also underreporting nonfatal accidents (CPWR 2013).

2.9 Conclusions and Recommendations

The construction industry's recordable injury rate has steadily been improving since the OSH Act was enacted. During this time safety research studies have mainly focused on large contractors, which is often difficult to extend to small contractors. While this study focused solely on small contractors, the sample size for this research study was too small to infer which safety leading indicators correspond with a better safety performance. 255 random construction interviews were needed to have a statistically significant sample and was the original research goal. Unfortunately, the cold call interview protocol was not as successful as originally hoped and resulted in barely a 2% response rate. If the statistically significant sample was to be obtained, over 11,000 phone calls would have to been made. Future construction safety research is definitely warranted for these companies, but the data collection technique needs modification.

This study contributes to the body of knowledge base by testing a devised research method for randomly selecting from a population, investigating safety leading indicator usage among those small contractors, and finding the barriers to implementation. The data suggest that there are a group of safety leading indicators that are common practices with the small contractors interviewed. Also, having 75% or more of a firm's workers employed for more than five years is strongly linked to an improved safety performance within the group that was studied. There are two potential reasons why contractors may have a better safety performance from low worker turnover that arises from previous literature. First, CPWR found that veteran craft workers are much less likely to be injured on a project than a younger worker (2013). This may be attributed to veteran workers having more experience in realizing hazards than their counterpart. In addition, successful contractors that build a strong safety culture do so by instilling safety as a core value for every worker (Cesarini et al. 2013). As a result, contractors with low worker turnover rates would theoretically have a better chance at building a strong safety culture compared to contractors with high turnover rates.

This research study also found the barriers to implementation of the strategies which most often included the view that these strategies were unnecessary or did not apply to small contractors. The author recommends future research to include case studies with well-established small contractors that have excellent safety records to discover what effective strategies are being practiced that sets these firms apart from the status quo. Safety strategies specific to small contractors are necessary because a previous study by another researcher analyzed these same indicators with large contractors to see if any indicator correlated with a better safety performance. The results from that study found ten leading indicators that were differentiators between a strong and weak safety performance for large contractors (Baud 2012). Those ten indicators for large contractors were not found to be linked with an improved safety performance for the small contractors in this study. As a result, future research should specifically find effective safety strategies linked to improved safety performances of small contractors.

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Chapter 3: Synergistic Effects among Leading Indicators of Construction Safety Performance from the Perspective of an Owner[1]

3.1 Abstract

Lagging indicators have been the traditional method to evaluate safety performance on a construction project. These metrics, such as the total recordable injury rate, are useful in evaluating risk but do nothing to prevent an accident that has already occurred. Conversely, leading indicators that are properly selected, measured and monitored have the ability to alert management prior to an accident. In an effort to provide guidance to owners of construction projects that are looking to develop or enhance a leading indicator program, this study analyzed the synergistic effects among thirteen metrics that have been previously identified as strong predictors of safety performance. The objective of this paper is to report the results of a Delphi panel that quantified the pairwise synergistic effects between thirteen leading indicators from an owner's perspective. Analysis of the data from the perspective of an owner show that the largest increase in effectiveness ranges from sixty to sixty-nine percent when project management team safety process involvement and pre-task planning are monitored on a construction project. Furthermore, the leading indicators with the greatest overall synergistic impact are pre-task planning, project management team safety process involvement, housekeeping program, owner safety walkthroughs, worker observation process, owner participation in worker orientation sessions, and stop work authority.

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CE Database subject headings: Construction management; Safety; Accidents; Fatalities.

Author keywords: Owners; Leading indicators; Labor and personnel issues.

3.2 Introduction

Historically, the occupation of "construction worker" has been one of the most dangerous jobs when compared to other industries and this is true all over the world. In fact, nearly all construction workers in the U.S. will experience at least one work-related injury during their career while having a 1-in-200 chance of dying while working on a project (CPWR 2013). Those statistics are much worse in countries that are undeveloped and have not passed or do not enforce legislation such as the Occupational Safety and Health (OSH) Act in the U.S. or the Health and Safety at Work Act in Great Britain. Regardless of where a construction project is located, any accident results in both economic losses and unquantifiable costs such as human suffering and the repercussions to the victim's family. In addition to those direct and indirect losses experienced by the contractor and the injured worker, there are other stakeholders including the owner of the project that are affected by a worker injury or fatality. According to the Construction Users Roundtable (CURT), one stakeholder that has the greatest leverage for keeping and maintaining a safe workplace during the life of a project is the owner (2004).

The owner can affect the safety performance experienced on a project through dynamic leadership and the understanding that their efforts influence safety (Huang and Hinze 2006). Traditionally though, owners have not taken an active role in construction safety due to fear of litigation and economic losses; however with the increase of legal cases with the owner as a third party defendant, some owners have decided not to ignore safety (CII 2003). One group in support of not ignoring safety by the owner is the CURT that developed four principles as a starting point for owners (CURT 2004). Those principles are:

1. Any construction-related injury, illness, damage to property, or the environment is unacceptable.
2. Owners should work to prevent all accidents.
3. The performance level achieved is whatever the organization is willing to accept.
4. Zero accident policy is the only acceptable goal.

Zero accident policies have been difficult for some to conceptualize because safety performance has traditionally been measured by lagging indicators that includes metrics such as the total recordable injury rate (TRIR) or the experience modification rate (EMR). While these are important evaluation metrics, they do not prevent an accident that has already occurred. If the construction industry as a whole is to achieve a zero accident policy, then a more proactive approach must be used for measuring safety performance. One proactive safety strategy that has increased in use for measuring safety performance of construction projects are leading indicators. Recently, one study identified and developed thirteen highly-effective leading indicators for measuring and predicting construction safety performance (Hallowell et al. 2013). In another study, researchers estimated that leading indicators could potentially experience synergistic effects when used concurrently to measure safety performance on a construction project (Hinze et al. 2013).

The purpose of this study was first, to determine if there were synergistic effects between leading indicators and secondly, if so, quantify those effects in terms of a percent increase in effectiveness for measuring safety performance. This was accomplished through a Delphi panel of experts that evaluated the percent increases in effectiveness from an owner's perspective for pairs of leading indicators. Pairs of leading indicators were evaluated because usually only a small set of indicators are monitored on a given project. Understanding the synergistic effects will help owners that have contractual safety requirements regarding leading indicators or monitor the construction project with leading indicators. The objective of this paper was to test the hypothesis that synergy is present between pairs of leading indicators. This hypothesis was tested through a Delphi study that quantified the synergistic effects between leading indicator pairs that have previously been connected to exceptional safety performance. Owners' can use these data to identify leading indicator pairs that are the most effective for measuring and monitoring safety performance during the project life cycle.

3.3 Literature Review

Research into owner involvement on a construction project began in the 1970's. Since that time there have been many studies. One of these earlier studies identified owner guidelines for how to select safe contractors to ensure a high level of safety performance for their project (Samelson and Levitt 1982). The overarching finding was that active owner participation in selecting and monitoring the contractor safety performance resulted in lower incident rates. Today, leading indicators are one method to monitor safety performance on a construction project. Figure 3.1 depicts how leading indicators compare to lagging indicators (Harding 2010).

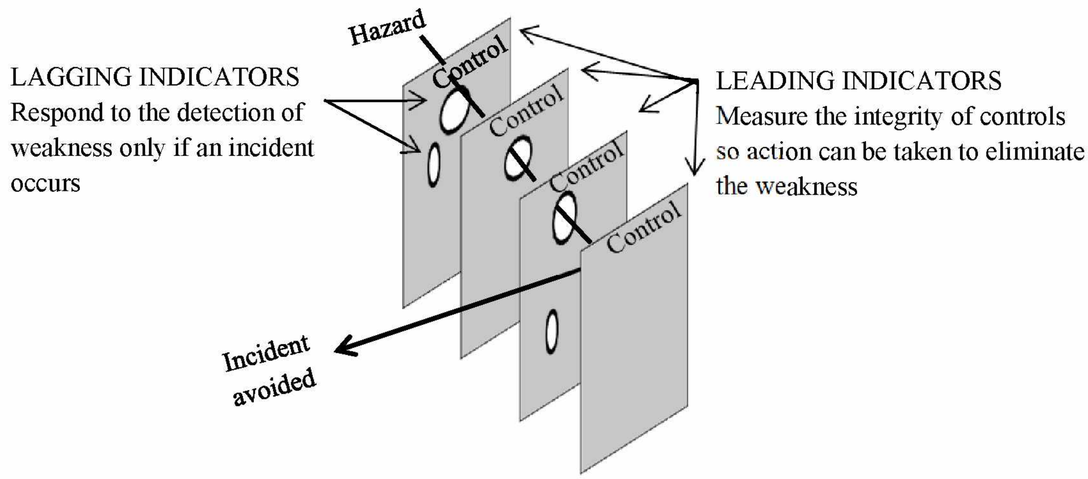

Figure 3.1 Relationship between Leading and Lagging Indicators (Harding 2010)

There are two types of leading indicators, passive and active. Passive leading indicators have the ability to predict the potential safety performance of a company. Although these indicators are unable to generally affect the work process in the short-term because passive leading indicators generally are difficult to change after a project has started. Examples of passive leading indicators include subcontractor selection and compliance, safety in construction contracts, and number of workers on-site that have an OSHA card to name a few. On the other hand, active leading indicators have the ability to affect a work process in the short term while the indicator is measured or controlled during the project lifecycle. There are many active leading indicators and a few include the percent of negative test results for substance abuse programs, the number of safety meetings and what percentage of supervisors are in attendance, or the percentage of supervisors and management in attendance at the preconstruction meeting are some examples.

In the past five years, the Construction Industry Institute (CII) has funded a research effort looking into leading indicators of construction safety performance. One of the results of that research effort identified thirteen leading indicators that are connected to exceptional safety performances on construction projects by large contractors. Those thirteen indicators are: near misses, project management team safety process involvement, worker observation process, stop work authority, auditing program, pre-task planning, housekeeping program, owner's participation in worker orientation sessions, foremen discussions and feedback meetings with the owner's project manager, owner safety walkthroughs, pre-task planning for vendor activities, vendor safety audits, and vendor exit debriefs (Hallowell et al. 2013). Around the same time another group of authors published an article hypothesizing that leading indicators measured on a project may experience synergistic effects at an improved safety performance (Hinze et al. 2013). Since that time these potential synergistic effects have not been quantified.

3.4 Point of Departure

The purpose of measuring leading indicators on a project is to predict future safety performance so an accident can be avoided. Often projects are monitored with more than one leading indicator and researchers have hypothesized that there are synergistic effects when multiple indicators are measured during a project. The purpose of this study was to conduct a Delphi study to determine if there are synergistic effects when pairs of leading indicators are used together from the perspective of an owner. Specifically, the thirteen leading indicators previously connected to exceptional project safety records were presented to owner representatives and they were asked to rate the percent increase in effectiveness of each pairwise interaction for measuring the safety performance of a project.

3.5 Research Methods

The synergistic effects among pairs of leading indicators were quantified through a structured survey using the Delphi method. This method was selected because it can address the challenges of safety research that often include: archival data are incomplete, experiments are unrealistic or unethical, and incidents occur on a relatively long timeline (Hallowell and Gambatese 2010). The remainder of this section will describe the characteristics of the method in relation to this study, expert requirements, number of panelists, number of rounds and feedback, survey design, and target consensus.

3.5.1 Delphi Method

The Delphi method was developed by the Rand Corporation in the early 1950's for the US Defense industry (Robinson, 1991). Since its origins, the Delphi method has been used by researchers from a variety of disciplines. Unfortunately, there are significant variations in how the method has been implemented. As a result, Hallowell and Gambatese developed a set of guidelines to help increase the reliability of research using the Delphi method specific to construction engineering and management (2010). The first guideline is to understand the traditional Delphi process.

The traditional Delphi process is a systematic approach to obtaining expert opinions leading to consensus through multiple rounds and anonymity. The process begins by selecting and qualifying individuals specific to the research topic. After being qualified the experts are asked to provide their opinion through a structured survey and after each round the facilitator compiles the results into an individualized structured survey that has each of the expert's previous responses and the group median. The experts are then asked to review their previous rating and the group median and consider changing their previous response or otherwise provide a response to the group about why they are more than ten percent away from the median. The purpose of the subsequent rounds is to achieve a group consensus around a correct rating or value. The process ends when a certain number of rounds are completed or consensus is achieved.

3.5.2 Number of Panelists

Previous Delphi studies have varied in the number of experts that participate in a given study. Brockhoff evaluated the accuracy of the Delphi method and how many experts were on the panel; his findings concluded that a panel should consist of eight to fifteen qualified people (1975). For this study eight people agreed to participate and were qualified as experts. Of the eight participants who agreed to participate, everyone completed all rounds of the Delphi process.

3.5.3 Expert Requirements

Experts were selected that have had experience utilizing leading indicators for measuring safety performance of construction projects from the perspective of an owner. Experts were qualified through a flexible point system that was based around objective criteria where each potential participant had to score at least ten points. Table 3.1 depicts the objective criteria and the number of points allotted for each criteria.

Table 3.1 Delphi Panel Qualification Criteria

Experience	Points (each)
Professional registration	3
Years of professional experience (1 point per year)	1
Years of construction safety management (1 point per year)	1
Years using proactive metrics for safety (1 point per year)	1
Conference presentation	0.5
Committee member	1
Committee chair	3
BS	4
MS	2
Ph.D.	4

The Delphi panel included eight professionals that had a total of 43 years' experience using leading indicators for measuring safety performance. Their professional experience included 98 years of Environmental, Health and Safety Management, 26 years of risk management, 33 years of project engineering, and 7 years of upper management. In addition, the group had six registered Certified Safety Professionals (CSP), one Certified Hazardous Materials Manager (CHMM), and one Certified Environmental, Safety and Health Trainer (CET). The education of the panel included seven bachelor degrees and two master degrees. In addition, the panel has given a total of 41 conference presentations related to construction. Finally, all panelists were currently participating in at least one committee relevant to construction safety.

3.5.4 Number of Rounds and Feedback

Previous Delphi studies by other researchers have ranged from only one round to sometimes more than four. However studies with only one round are hardly recognized as a Delphi process. Dalkey (1971) found that results were most accurate after the second and third rounds followed by becoming less accurate in subsequent rounds. There are other researchers that contend that a study should continue until consensus is achieved. Given the time frame for this study and the extensive time commitment of the participants, this Delphi process was determined to continue through three rounds with detailed feedback after the second and third round.

3.5.5 Survey Design

The purpose of the survey design was to quantify the percent increase in effectiveness for measuring safety performance when leading indicator A is used with leading indicator B. The pairwise interactions were considered to be one-way interactions and thirteen leading indicators were identified from previous research to be used in this study resulting in 78 ratings required by each expert for each round. An example of the structured survey from Round 1 is included as Figure 3.2.

DIRECTIONS: Put an "**X**" in the box that indicates the relative percent increase in effectiveness for measuring the safety performance on a project when monitoring **NEAR MISSES** combined with monitoring each of the safety leading indicators below.

		Percent increase in effectiveness that measuring NEAR MISSES combined with measuring each of the following:								
		% Increase in effectiveness for measuring safety performance								
Measurement of the following Safety Leading Indicator	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-100
Project mgmt. team safety process involvement										
Worker observation process										
Stop work authority										
Auditing program										
Pre-task planning										
Housekeeping program										
Owner's participation in worker orientation sessions										
Foremen discussions and feedback meetings with the owner's PM										
Owner safety walkthroughs										
Pre-task planning for vendor activities										
Vendor safety audits										
Vendor exit debrief										

Figure 3.2 Example Round 1 Survey Sheet

3.5.6 Target Consensus

Gaining consensus on a research topic among a group of qualified experts is the main objective of the Delphi process. As a result, measuring consensus is an important aspect that must be determined prior to round one of the Delphi process. Previous studies have often measured consensus by either the standard deviation or the absolute deviation depending on if group means or medians are collected. This study used group medians rather than means because of a less likelihood of being influenced by outlying responses. The goal of the study was to bring the group of experts to an ultimate absolute deviation of less than ten percent. The ultimate absolute deviation refers to the average deviation from the median. This was calculated for each of the 78 ratings, followed by taking the average of all of the ultimate absolute deviations to find when consensus was reached.

3.6 Results

The Delphi study was managed over a two-month period with three-weeks for each round. Each expert was given two weeks to provide ratings and afterwards one week was set aside for the facilitator to compile the results for each round. The duration of response time was longer than other Delphi studies due to each panelist being required to provide 78 ratings per round for three rounds. Out of the eight qualified experts that agreed to participate, all eight completed the three rounds of surveys. Overall, 1,872 ratings were collected from the Delphi panel.

The purpose of the Delphi method is to bring a group of experts to consensus. The overall average absolute deviation of all ratings was 9.47% after the first round, 8.46% after the second round, and finally 7.64% after the third round. The pairwise group median effectiveness ratings are provided in Table 3.2.

Table 3.2 Pairwise Impacts in Percent Increases of Effectiveness for Construction Safety Performance Measurements from the Perspective of an Owner

	Range of relative percent increase in effectiveness for measuring safety performance when monitored together																					
	Project management team safety process involvement		Worker observation process		Stop work authority		Auditing program		Pre-task planning		House-keeping program		Owner participation in worker orientation sessions		Foremen discussions and feedback meetings with owner's project manager		Owner safety walk-throughs		Pre-task planning for vendor activities		Vendor safety audits	
Near-miss reporting	50	59	40	49	48	57	30	39	40	49	40	49	30	39	30	39	38	47	30	39	20	29
Project management team safety process involvement			50	59	49	58	39	48	60	69	41	50	40	49	41	50	50	59	40	49	33	42
Worker observation process					39	48	30	39	55	64	40	49	39	48	40	49	39	48	43	52	30	39
Stop work authority							30	39	49	58	49	58	40	49	30	39	40	49	30	39	30	39
Auditing program									40	49	40	49	39	48	30	39	39	48	20	29	20	29
Pre-task planning											49	58	49	58	49	58	40	49	40	49	30	39
Housekeeping program													49	58	40	49	49	58	30	39	30	39
Owner participation in worker orientation sessions															40	49	40	49	40	49	30	39
Foremen discussions and feedback meetings with owner's project manager																	40	49	35	44	30	39
Owner safety walkthroughs																			40	49	43	52
Pre-task planning for vendor activities																					35	44
Vendor safety audits																						

These Round 3 data represent the group median ranges of relative percent increases in effectiveness for measuring safety performance from the perspective of an owner. All ratings were between a relative percent increases in effectiveness of 20 to 69 percent. Table 3.3 shows the pairs of leading indicators that had the greatest percent increases in effectiveness.

Table 3.3 Most Significant Percent Increases in Effectiveness for Measuring Safety Performance from the Perspective of an Owner

Leading indicator pairs		% increase
Project management team safety process involvement	Pre-task planning	60-69%
Worker observation process	Pre-task planning	55-64%
Project management team safety process involvement	Worker observation process	50-59%
Near-miss reporting	Project management team safety process involvement	50-59%
Project management team safety process involvement	Owner safety walkthroughs	50-59%
Project management team safety process involvement	Stop work authority	49-58%
Stop work authority	Pre-task planning	49-58%
Stop work authority	Housekeeping program	49-58%
Pre-task planning	Housekeeping program	49-58%
Pre-task planning	Owner participation in worker orientation sessions	49-58%
Pre-task planning	Foremen discussions and feedback meetings with owner's project manager	49-58%
Housekeeping program	Owner participation in worker orientation sessions	49-58%
Housekeeping program	Owner safety walkthroughs	49-58%
Near-miss reporting	Stop work authority	48-57%

Additionally the least significant pairs of leading indicators are presented in Table 3.4.

Table 3.4 Least Significant Percent Increases in Effectiveness for Measuring Safety Performance from the Perspective of an Owner

Leading indicator pairs		% increase
Near-miss reporting	Vendor safety audits	20-29%
Near-miss reporting	Vendor exit debrief	20-29%
Auditing program	Pre-task planning for vendor activities	20-29%
Auditing program	Vendor safety audits	20-29%
Auditing program	Vendor exit debrief	20-29%

3.7 Analysis

A simple analysis depicts the extent that a specific leading indicator can contribute overall. This was completed by summing all of the percent increases for each indicator. For example, each leading indicator can be paired with twelve other indicators for a total of twelve ratings for each indicator. Those twelve ratings were summed for each indicator to find the overall synergistic impact given for each. Table 3.5 includes these data.

Table 3.5 Synergistic Overall Impact of Each Leading Indicator

Leading indicator	Synergistic overall impact
Pre-task planning	1168
Project management team safety process involvement	1158
Housekeeping program	1080.5
Owner safety walkthroughs	1080.5
Worker observation process	1055.5
Owner participation in worker orientation sessions	1038
Stop work authority	1033
Foremen discussions and feedback meetings with owner's project manager	978
Near-miss reporting	938
Pre-task planning for vendor activities	933
Auditing program	860.5
Vendor safety audits	838
Vendor exit debrief	803

It's no surprise that pre-task planning has the most synergistic impact among the other leading indicators given that in Table 3.3 pre-task planning appeared the most and was one of the indicators of the pair that had the greatest percent increase in effectiveness. In addition, the indicators at the bottom of Table 3.5 are the same indicators that appear the most in Table 3.4, which shows the least significant pairs of indicators. It's important to note that these measures are unit-less and only provide a relative value for comparing the overall synergistic impact of each leading indicator. This information may be useful to owner companies that either have contractual requirements for contractors to use specific leading indicators or are monitoring the safety performance of the project with an owner's representative. Presently, there has not been a study that evaluates the individual effectiveness of each leading indicator; however knowing the effectiveness synergy between indicators may be useful when two are three indicators are used to monitor safety performance. Monitoring two or three leading indicators is the general practice for monitoring safety performance on a construction project (Hinze et al. 2013). From the perspective of an owner, the indicators with higher scores suggest a greater synergistic overall impact towards the effectiveness of predicting future safety performance. From Table 3.5, it is clear that pre-task planning, project management team safety process involvement, housekeeping program, owner safety walkthroughs, worker observation process, and owner participation in worker orientation sessions have more of a synergistic overall impact than other indicators with lower scores. These findings build on the body of construction safety knowledge by quantifying the synergistic relationships between leading indicators of construction safety performance.

3.8 Conclusions

The purpose of this research study was to quantify the synergistic impacts between thirteen leading indicators of construction safety performance through a Delphi panel of experts. The experts came to a consensus that from the perspective of an owner there are positive synergistic impacts between leading indicators when used in conjunction on a construction project for measuring safety performance. Some of the most important pairs of indicators are between pre-task planning, project management team safety process involvement, worker observation program, near-miss reporting, and owner safety walkthroughs. Conversely, some of the least important indicators from an owner's perspective included an auditing program, pre-task planning for vendor activities, vendor safety audits, and vendor exit debriefs.

These results can be used by owner companies that use specific contractual requirements regarding leading indicators or monitor safety performance on a construction project with a set of leading indicators. Owner representatives are encouraged to consider the results when selecting a set of leading indicators to monitor on a construction project. Furthermore, proper use of the leading indicators has been proven to result in improved lagging indicators which may potentially further build management support of using leading indicators.

There are some limitations that should be considered from this study. First, all of these experts had significant experience with measuring and monitoring leading indicators. However, each project differs and while the eight experts came to a consensus, leading indicators should be carefully selected to fit the project. Take for example OSHA's "fatal four", within the private industry the top four leading causes of death include falls, struck by object, electrocution, and caught-in or between (OSHA 2013). Depending on the type of project, these leading causes of accidents should be evaluated for their likelihood to occur during the work to be performed and the most relevant set of indicators to be monitored should subsequently be selected. Another limitation is only thirteen indicators were studied that had previously been connected to exceptional safety performance. From the literature review, there are hundreds of leading indicators that have been identified in construction safety research and studying the synergistic effects between more indicators would be useful but was outside the scope of this study.

Future research that quantifies the individual effectiveness of the thirteen leading indicators could be combined with the results from this study to further evaluate the overall effectiveness of each indicator. In addition, finding other leading indicators that are connected to exceptional safety records and finding their synergistic impact would help to compare against the results of this study for the purpose of finding the indicators with the most impact. In addition, finding owner companies that use or require their contractor to use leading indicators for monitoring safety performance and comparing the differences in how those indicators are being measured would be helpful for those beginning to develop a leading indicator measurement program. Finally, compiling and publishing the best practices for each leading indicator from construction project owners that have had exceptional project safety performances would be beneficial to owners that are new to leading indicator monitoring.

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Chapter 4: Synergistic Effects among Leading Indicators of Construction Safety Performance from the Perspective of a Contractor[1]

4.1 Abstract

Traditionally, lagging metrics have been used to evaluate a construction contractor's safety performance and are based on their past safety performance. Conversely, leading indicators have the ability to be measured and monitored during the project lifecycle and alert management before an accident occurs. It has been hypothesized that when leading indicators are used in conjunction on a project, synergistic effects may increase their effectiveness. Through a Delphi process, a panel of experts quantified the pairwise synergistic effects between thirteen leading indicators that have previously been found to be strongly connected to exceptional safety performance. The objective of this study was to test the hypothesis that synergy is present between pairs of leading indicators and that has an impact on their overall effectiveness. These synergistic effects were quantified from the perspective of a contractor by a Delphi panel of qualified construction safety experts. The analysis of data indicates that monitoring near-miss reporting and pre-task planning on a project has a 70 to 79 percent increase in effectiveness for measuring safety performance. In addition, the leading indicators that had the greatest overall synergistic impact were found to be pre-task planning, near-miss reporting, worker observation process, an auditing program, and project management team safety process involvement. Results from this study are expected to be beneficial to all sizes of contractors that are looking to implement or enhance their leading indicator monitoring program.

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CE Database subject headings: Construction management; Safety; Accidents; Fatalities.

Author keywords: Contractors; Leading indicators; Labor and personnel issues.

4.2 Introduction

Accident data reported by the Center for Construction Research and Training (CPWR) in their most recent Construction Chart Book show that the fatality rate for the U.S. is relatively high in comparison to other industrialized countries. Specifically, the U.S. had 9.7 deaths per 100,000 full-time equivalent workers and the only other countries with a higher fatality rate were Spain and Italy with 10.6 and 10.0 (CPWR 2012). While these rates are alarming they are vast improvements from the era when the Occupational Safety and Health Administration (OSHA) was formed in the United States when the construction fatality rate was 71 deaths per 100,000 equivalent full-time workers (NSC 2006). Regardless the country, injuries and fatalities bring a host of direct and indirect effects that can influence a contractor such as: decreased productivity resulting from investigations, reduced worker morale that influences the safety culture, negative changes in metrics used for project prequalification bids, followed by the costs that may not be fully realized for years.

According to the Construction Financial Management Association (CFMA) there is a culture shift within the industry towards a *zero accident vision (ZAV)* (Beyer and Lambert 2013). A *ZAV* is a true belief that injuries and fatalities can be eliminated within the industry. This is not a new phenomenon, but instead has been around since at least 1993 when the Construction Industry Institute (CII) published the *Zero Injury Techniques* (CII 1993). Since that time a growing number of construction contractors have instituted the concept of a *ZAV*. One of the strategies that these companies employ is leading indicator measurement in addition to continuing the use of traditional lagging indicators. While lagging metrics are important for evaluating the effectiveness of a safety program, the indicators take a reactive approach. On the other hand, leading indicators measure processes, activities, and conditions which provides direction to where corrective action is needed (CII 2012).

Globally, there have been many organizations and agencies that have recognized the importance of leading indicators. One of those agencies in the U.S. is the National Institute for Occupational Safety and Health (NIOSH) which created the National Occupational Research Agenda (NORA) in 1996. Recently the NORA Construction Sector Council identified fifteen research goals with one pertaining to developing and disseminating guidance to the construction industry on leading indicator metrics for safety and health performance (NORA 2008). Recently, there have been a number of studies surrounding leading indicators. One of those studies identified thirteen leading indicators that were found to be connected to exceptional safety performance (Hallowell et al. 2013). Around the same time, another study hypothesized that there were potential synergistic effects among leading indicators being measured and monitored together on a project (Hinze et al. 2013). Since that time, the synergistic effects among leading indicators have yet to be explored from the perspective of a contractor.

The purpose of this study was to test the hypothesis that synergy is present between leading indicators which make some more effective than others at measuring the safety performance of a contractor. To test this hypothesis, a Delphi panel of experts was assembled to quantify the pairwise synergistic effects among thirteen leading indicators previously connected to exceptional safety performance from the perspective of a contractor. It is predicted that the results from this study can be used by construction contractors looking to develop leading indicators to measure or enhance their current safety program.

4.3 Literature Review

Safety metrics can be divided into two categories, leading indicators and the more traditional lagging indicators. Lagging indicators are used throughout the industry and include metrics such as the total recordable injury rate (TRIR), experience modification rate (EMR), or the days away, restricted or job transfer rate (DART). These reactive measures are important for risk evaluation and looking at historical trends, but these metrics are not preventative. On the other hand, leading indicators when properly measured and monitored have the ability to alert safety personnel to holes in the safety management system so action can be taken to prevent an accident. Toellner (2001) defines leading indicators as metrics that are linked to preventive actions. These actions preventing an accident can be seen in Figure 4.1 as opposed to lagging indicators (Harding 2010).

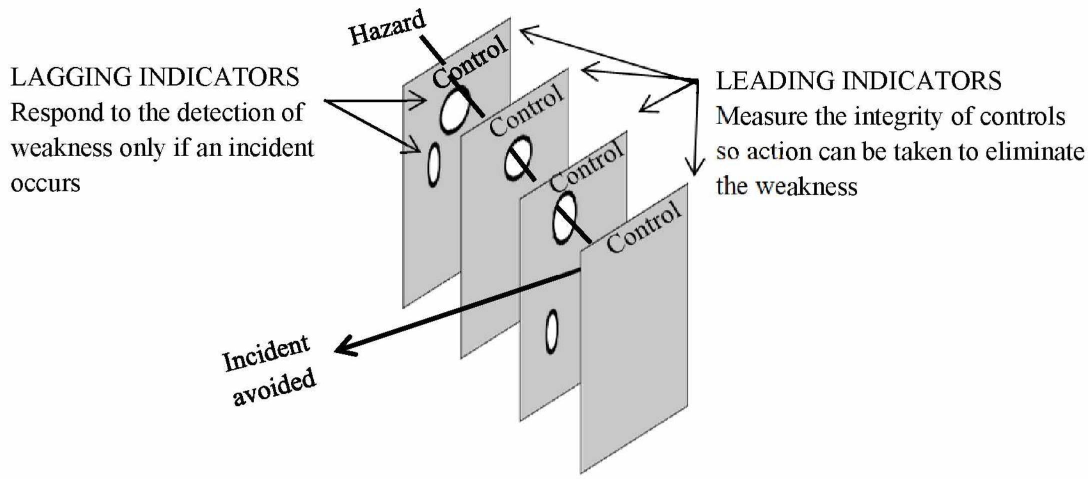

Figure 4.1 Relationship between Leading and Lagging Indicators (Harding 2010)

According to the CII, there are two types of leading indicators: passive and active. Passive leading indicators are strategies related to safety that are implemented before the project begins and usually cannot be adjusted after. A couple examples are: the percentage of workers with a 30-hour OSHA card or the level of contractual safety requirements for the contractor. Conversely, active leading indicators can be measured and adjusted during the project life cycle for the purpose of monitoring and improving future safety performance. Two examples of active leading indicators are: percentage of management attending the jobsite safety meetings or the percentage of compliance of the jobsite safety audits. Future safety performance is improved through continual monitoring of active leading indicators that can trigger a response prior to an accident occurring (CII 2012). Monitoring leading indicators has been one strategy that companies have used towards achieving a *ZAV*.

Until recently there has not been any guidance to contractors on what are the most effective leading indicators at predicting future safety performance. One of the first publications identified leading indicators being used by some of the largest contractors in the industry and validated the findings against empirical data (Hallowell et al. 2013). The study found thirteen leading indicators that are strong indicators of future safety performance for a construction project. The thirteen leading indicators from the study were: near-miss reporting, project management team safety process involvement, worker observation process, stop work authority, an auditing program, pre-task planning, housekeeping program, owner's participation in worker orientation sessions, foremen discussions and feedback meetings with the owner's project manager, owner safety walkthroughs, pre-task planning for vendor activities, vendor safety audits, and vendor exit debriefs. The researchers from that study also provided examples of how each leading indicator could be measured and monitored, but threshold values were not developed because they are highly influenced by the organization's current safety culture (Hallowell et al. 2013). During the same time, another group of researchers hypothesized that synergistic impacts could have potential increases in effectiveness for predicting future safety performance when used in conjunction on a project (Hinze et al. 2013).

4.4 Point of Departure

Contractors using leading indicators for measuring safety performance on a project often use more than one metric and researchers have hypothesized that there are potential synergistic effects when more than one is used. The purpose of this study was to quantify the pairwise synergistic effects among thirteen leading indicators through a Delphi process from the perspective of a contractor. The synergistic effects will be quantified by rating the percent increase in effectiveness for measuring safety performance of each pairwise interaction.

4.5 Research Methods

A structured survey using the Delphi method was selected to quantify the synergistic effects among pairs of leading indicators. The Delphi method was chosen because it can address the weaknesses of safety research that consist of: archival data being incomplete, incidents occurring on a relatively long timeline, and experiments being unrealistic or unethical (Hallowell and Gambatese 2010). In addition, the quantity of ratings required was better suited for a group rather than relying on one expert's ratings. The remainder of this section will describe the characteristics of the Delphi method, expert requirements, number of panelists, number of rounds and feedback, survey design, and target consensus for this research study.

4.5.1 Delphi Method

The Delphi method was developed in the 1950's for forecasting by the Rand Corporation (Robinson, 1991). Since that time, the Delphi method has been used by researchers from a variety of disciplines ranging from medicine to logistics. However, there are significant differences in how the method has been used in the past resulting in some researchers questioning its validity. To help researchers in the area of construction engineering and management, a recent journal article developed a set of guidelines to enhance the reliability of the method (Hallowell and Gambatese 2010). The first guideline of the Delphi method is to understand the process.

The traditional Delphi process is a systematic approach for obtaining expert opinions leading to a group consensus through multiple rounds, statistical feedback, and anonymity. After identifying the research question and how consensus will be measured, potential experts are selected through a qualification process of pre-defined criteria. After being qualified as experts, panelists are asked to provide their opinion through a structured survey developed around the research question. The surveys are returned to the facilitator and the results are compiled to analyze the group consensus. The target consensus is calculated through taking the overall average of all the absolute deviations from the median of the group. If the target consensus is not achieved, individualized surveys are developed that depict the expert's previous response and the overall group median. Afterwards, the surveys are transmitted back to the experts who are then given the opportunity to review their previous response and the group median. The experts have the option to change their initial response or keep their original value. In the event the expert's response is outside the target consensus range of the median, that expert is asked to provide a reason for their outlying value. After the second round, responses are collected and analyzed against the target consensus for evaluating the need for a third round. In the event the target consensus is not achieved, a third round is conducted where the each expert will see their previous response, the group response, and the reasons for outlying responses. Each expert again has the opportunity to change their response before another target consensus is calculated. This process ends when the target consensus is achieved or a number of rounds have been completed.

4.5.2 Expert Requirements

Leading indicator measurement is not widespread in the construction industry and is generally used by only large contractors (Hallowell et al. 2013). As a result, experts selected for this study were limited to those with experience measuring safety performance with leading indicators. To qualify as an expert, a flexible point system was based around objective criteria where each potential participant had to score at least ten points. Table 4.1 depicts the objective criteria and the number of points allotted for each.

Table 4.1 Delphi Panel Qualification Criteria

Experience	Points (each)
Professional registration	3
Years of professional experience (1 point per year)	1
Years of construction safety management (1 point per year)	1
Years using proactive metrics for safety (1 point per year)	1
Conference presentation	0.5
Committee member	1
Committee chair	3
BS	4
MS	2
Ph.D.	4

The experts gathered for this study were well qualified to quantify the pair-wise synergistic effects among the thirteen leading indicators identified in the research question. The panel included seven professionals who had a total of 52 years of experience using leading indicators for measuring safety performance. Their professional experience consisted of 72 years of environmental, health and safety management and 27 years of risk management. In addition, the group certifications in total were five registered certified safety professionals (CSP), two associates in risk management (ARM), two safety trained supervisors (STS), one certified safety and health manager (CSHM), one certified professional environmental auditor (CPEA), two occupational health and safety technologists (OHST), three construction health and safety technicians (CHST), and one construction risk and insurance specialist (CRIS). The education of the panel included two associate degrees, six bachelor degrees, and 4 master degrees. In addition, the panel has given a total of over 46 conference presentations, published 7 research articles, and written over 24 magazine articles. Finally, the group has been involved in six local and national committees related to construction.

4.5.3 Number of Panelists

The number of experts for a Delphi panel has varied greatly when reviewing previous studies. One researcher evaluated the accuracy of the Delphi method and how many experts were on the panel and concluded that a panel should consist of eight to fifteen qualified people (Brockhoff 1975). For this study eight people were qualified as experts for the panel at the beginning of the study with seven panelists completing the Delphi process.

4.5.4 Number of Rounds and Feedback

Previous Delphi studies have ranged from only one round to sometimes more than four. However, Dalkey concluded that results were most accurate after the second and third rounds and became less accurate in subsequent rounds (Dalkey 1971). Given the extensive time commitment of the participants, this Delphi process was determined to continue through three rounds with detailed feedback after the second and third round unless consensus was reached prior.

4.5.5 Survey Design

The purpose of the survey design was to quantify the pairwise synergistic relationships between indicators. This relationship was evaluated for all pairs of indicators through the percent increase in effectiveness for measuring safety performance on a project. The pairwise synergistic effects were considered among thirteen leading indicators resulting in 78 ratings required by each expert for each round. An example of the structured survey from Round 1 is included as Figure 4.2.

DIRECTIONS: Put an "**X**" in the box that indicates the relative percent increase in effectiveness for measuring the safety performance on a project when monitoring **NEAR MISSES** combined with monitoring each of the safety leading indicators below.

		Percent increase in effectiveness that measuring NEAR MISSES combined with measuring each of the following:								
		% Increase in effectiveness for measuring safety performance								
Measurement of the following Safety Leading Indicator	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-100
Project mgmt. team safety process involvement										
Worker observation process										
Stop work authority										
Auditing program										
Pre-task planning										
Housekeeping program										
Owner's participation in worker orientation sessions										
Foremen discussions and feedback meetings with the owner's PM										
Owner safety walkthroughs										
Pre-task planning for vendor activities										
Vendor safety audits										
Vendor exit debrief										

Figure 4.2 Example of a Structured Survey from Round 1

4.5.6 Target Consensus

The main purpose of the Delphi method is to gain consensus about a research question from a group of qualified experts. As a result, defining how the group consensus will be measured in a Delphi study is an integral aspect and should be determined before data collection. Previous studies often collected the group mean or median in order to calculate the standard or absolute deviation and determine if it meets a pre-defined range of acceptability. This study opted to calculate medians rather than means because medians are not influenced by outlying responses. The target consensus for the study was to bring the group of experts to an ultimate absolute deviation of less than ten percent. The ultimate absolute deviation refers to the average of all absolute deviations from the median. A simple example can illustrate this, if there were three panelists (1, 2, and 3) that gave ratings on three indicators (A, B, and C). The hypothetical ratings for indicator A were (30, 50, and 70), indicator B were (20, 40, 60), and finally indicator C ratings were (10, 20, and 30). The median for indicator A would be 50 and the absolute deviation from the median for panelist 1 would be the absolute value of 30 minus 50, for panelist 2 it would be the absolute value of 50 minus 50, and panelist 3 would be the absolute value of 70 minus 50. These absolute deviations for indicator A (20, 0, and 20) would be then averaged for an averaged absolute deviation of 13.33 percent. This would be calculated for each of the other indicators and then all of the averages of the absolute deviations for all indicators will be averaged for the ultimate absolute deviation. In this example, the ultimate absolute deviation was found to be 11.11 percent. For this study, the target consensus was ten percent and if the ultimate absolute deviation was more than another Delphi round was required.

4.6 Results

The Delphi panel was given two weeks for each round to provide their ratings. After each round one week was set aside to compile the results followed by creating an individualized survey for each respondent. A total of three rounds were facilitated over a two-month period where each panelist provided 78 ratings per round for three rounds. Seven of the eight panelists who were initially qualified, completed all three rounds, and 1,830 ratings in total were collected.

The main objective of the Delphi method is to bring a group of experts to consensus through feedback and anonymity. Consensus was determined to occur when the overall average absolute deviation of all the ratings was less than ten percent. After round one the overall absolute deviation was at 17.66%, 13.40% after the second, and 9.51% after the final round. The defaulting panelist dropped out of the study between the second and third round. The pairwise median effectiveness ratings for the group are shown in Table 4.2.

Table 4.2 Pairwise Impacts in Percent Increases of Effectiveness for Construction Safety Performance Measurements from the Perspective of a Contractor

	Range of relative percent increase in effectiveness for measuring safety performance when monitored together																							
	Project management team safety process involvement		Worker observation process		Stop work authority		Auditing program		Pre-task planning		House-keeping program		Owner participation in worker orientation sessions		Foremen discussions and feedback meetings with owner's project manager		Owner safety walk-throughs		Pre-task planning for vendor activities		Vendor safety audits		Vendor exit debrief	
Near-miss reporting	50	59	30	39	50	59	40	49	70	79	40	49	60	69	38	47	25	34	40	49	10	19	10	19
Project management team safety process involvement			30	39	40	49	30	39	65	74	30	39	30	39	30	39	30	39	30	39	10	19	10	19
Worker observation process					30	39	50	59	60	69	60	69	40	49	20	29	20	29	30	39	10	19	10	19
Stop work authority							20	29	40	49	30	39	30	39	20	29	20	29	10	19	20	29	0	9
Auditing program									50	59	50	59	40	49	30	39	40	49	20	29	10	19	10	19
Pre-task planning											60	69	20	29	30	39	10	19	30	39	20	29	10	19
Housekeeping program													30	39	20	29	30	39	10	19	10	19	10	19
Owner participation in worker orientation sessions															40	49	20	29	10	19	0	9	0	9
Foremen discussions and feedback meetings with owner's project manager																	35	44	20	29	10	19	5	14
Owner safety walkthroughs																			10	19	10	19	5	14
Pre-task planning for vendor activities																					20	29	10	19
Vendor safety audits																							10	19

These median data of the group indicate the relative range of percent increases in effectiveness for measuring safety performance from the perspective of a contractor. These medians range from a low of 0-9 percent increase in effectiveness to a high of 70-79 percent. It is important to note that these ranges are the group consensus and were decided through expert opinion. Table 4.3 shows the most significant percent increases in effectiveness and what pairs of leading indicators that correspond with them.

Table 4.3 Most Significant Percent Increases in Effectiveness for Measuring Safety Performance from the Perspective of a Contractor

Leading indicator pairs		% increase
Near-miss reporting	Pre-task planning	70-79%
Project management team safety process involvement	Pre-task planning	65-74%
Worker observation process	Pre-task planning	60-69%
Worker observation process	Housekeeping program	60-69%
Near-miss reporting	Owner participation in worker orientation sessions	60-69%
Pre-task planning	Housekeeping program	60-69%
Near-miss reporting	Project management team safety process involvement	50-59%
Near-miss reporting	Stop work authority	50-59%
Worker observation process	Auditing program	50-59%
Auditing program	Pre-task planning	50-59%
Auditing program	Housekeeping program	50-59%

The least significant pairs of leading indicators are also shown in Table 4.4.

Table 4.4 Least Significant Percent Increases in Effectiveness for Measuring Safety Performance from the Perspective of a Contractor

Leading indicator pairs		% increase
Stop work authority	Vendor exit debrief	0-9%
Owner participation in worker orientation sessions	Vendor safety audits	0-9%
Owner participation in worker orientation sessions	Vendor exit debrief	0-9%
Foremen discussions and feedback meetings with owner's project manager	Vendor exit debrief	5-14%
Owner safety walkthroughs	Vendor exit debrief	5-14%

4.7 Analysis

The overall synergistic effects and the extent that a specific leading indicator can contribute can be calculated through a simple analysis. This simple analysis was completed by taking the summation of each percent increase for a particular indicator. For example, pre-task planning has twelve ratings of percent increase in effectiveness with the other indicators. A summation was taken of those ratings to give an overall synergistic impact value. Table 4.5 depicts these values.

Table 4.5 Synergistic Overall Impact of Each Leading Indicator

Leading indicator	Synergistic overall impact
Pre-task planning	1038
Near-miss reporting	1033
Worker observation process	888
Auditing program	888
Project management team safety process involvement	878
Housekeeping program	868
Owner participation in worker orientation sessions	748
Stop work authority	728
Foremen discussions and feedback meetings with owner's project manager	703
Owner safety walkthroughs	618
Pre-task planning for vendor activities	588
Vendor safety audits	388
Vendor exit debrief	288

It is important to note that these values are unit-less and are a measure of the overall synergistic impact for each leading indicator. These data have the potential to be useful to contractors that are just beginning to measure leading indicators or need to enhance their current program. According to the Delphi panel from a contractor's point of view, the leading indicators with a higher score should be implemented first as opposed to the indicators at the bottom of Table 5. From Table 5, the leading indicators that have more of a synergistic impact from a contractor's point of view are pre-task planning, near-miss reporting, worker observation process, auditing program, and project management team safety process involvement. Examples of how these indicators can be measured have been developed by other researchers (Hallowell et al. 2013). From that study, an example of measuring pre-task planning is by the percentage of pre-task plans prepared for work tasks. Near-miss reporting could be measured as a three-month moving average of near misses per a determined amount of worker-hours of exposure. Worker observation process could also be a 3-month moving average of the number of safety observations per worker-hours. An auditing program could be measured as the percentage of audited items not in compliance. Finally, project management team safety process involvement could measure the frequency of project management team participation in a project's safety activities (Hallowell et al. 2013).

4.8 Conclusions

The objective of this research study was to test the hypothesis that synergy was present between indicators, followed by quantifying the pairwise synergistic relationships between leading indicators from the perspective of a contractor through a Delphi process. The group of experts was able to achieve the target consensus that was measured by the overall average of the absolute deviations. Some of the greatest increases in effectiveness from a contractor's point of view included pre-task planning and near-miss reporting. On the other hand, the indicators with the least synergistic impact included vendor exit debriefs and vendor safety audits.

These results can be used by contractors that are looking to select leading indicators for measuring safety performance on a project or to enhance their current program. Furthermore, large contractors are the primary companies using leading indicators, but as the industry continues to move towards implementing these proactive metrics it is expected that small and medium sized companies may begin to utilize them. Therefore, companies just beginning to measure safety with leading indicators are encouraged to use the results from this study to help identify those indicators that should be implemented and to adjust the threshold measurements to the individual company and project. In addition, one of the barriers to using leading indicators identified from this study was the lack of management support. The results from this study may begin to help build management support for leading indicator use if those companies understood the percent increases in effectiveness for measuring safety performance when these indicators are monitored together on a construction project. For example, measuring near-miss reporting and pre-task planning together on a project were found have a 70 to 79 percent increase in effectiveness for measuring safety performance.

There are limitations to this study that should be considered. First, Delphi studies in the past have ranged in the number of participants, but some researchers conclude that a Delphi panel should consist of eight to twelve experts. This study began with an eight person panel; however one expert dropped out after the second round resulting in seven experts finishing the Delphi process.

It is unknown what the defaulting expert's ratings would have been in their third and final round, but taking their second round responses and leaving them unchanged still resulted in the panel achieving the target consensus. Secondly, the results from this study are a starting point for contractors and deciding how the indicator will be measured and the threshold values are vital considerations that should be specific to the project. For example, monitoring a three month moving average of the number of near-misses per worker hours is dependent on the size of the project and the number of workers to determine what the threshold value should be. Finally, the scope of this study only allowed for thirteen leading indicators to be studied that have previously been found to be connected to exceptional safety performances. There may be more indicators in the future that will also be connected to an improved safety record. In that event, exploring the synergistic effects between those new indicators would be interesting to compare to the results from this study.

Future research into the individual effectiveness of each indicator would be useful to combine with the results from this study to further help contractor selection of leading indicators. In addition, studying how contractors' are measuring leading indicators and their monitoring program would be beneficial for other contractors that are beginning to use this proactive approach. Those measures may not be initially applicable to a contractor beginning this process, but knowing the transition and adjustment as a company's safety culture develops would be useful. In addition, the contractor's safety record could be monitored over time as the use of leading indicators develops to see the level of safety performance improvement. Finally, future research that takes a best practices approach into leading indicators by studying contractors that have an exceptional safety record and a long track record of leading indicator use would be beneficial to the industry.

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Chapter 5: General Conclusions and Recommendations

The objectives of this three-part study were, first, to determine the current usage and barriers to future use of safety leading indicators by small contractors. This was accomplished through telephone interviews of twenty-five small contractors that employed less than ten workers. The second objective of this study quantified the pairwise synergistic effects among thirteen leading indicators from the perspective of an owner, and the third objective was similar but from the perspective of a contractor. These synergistic effects were quantified through a Delphi process that consisted of a separate panel of experts for each perspective. The results from these studies add to the body of knowledge of construction safety through finding the usage of leading indicators by small contractors and also quantifying the synergistic effects between pairs of leading indicators from the perspective of an owner and that of a contractor. It has been previously found that companies select safety strategies through intuition and peer suggestion (Hallowell and Gambatese 2009). It is expected that these results will help companies' selection process that are looking to enhance or beginning to develop a leading indicator program for measuring safety performance.

An important finding from the first phase of the research study found two leading indicators that are strongly linked to a lower TRIR for the small contractors interviewed. Those two leading indicators were 75 percent or more of workers employed for more than five years and 100 percent of workers employed for more than five years. This finding corresponds with other research studies that have found older workers have fewer accidents then younger workers (Salminen 2004; Kossoris 1948). Future research will be able to determine if there are other leading indicators that are also strongly linked to a lower TRIR for small contractors.

The interviews of small contractors revealed some of the barriers to using leading indicators. The barriers expressed by the small contractors most often given included: unnecessary, the company was too small, not enough time, perceived as ineffective, and cost. These responses indicate the need for future research into cost-effective strategies for small contractors. This is no surprise since one of the research goals of the NORA construction sector is for researchers to develop studies aimed at small contractors since they have largely been ignored in academic journals for 40 years (NORA 2008). To help change the lack of information for these firms, future research should take a best practices approach and find small contractors with exceptional safety records to discover what sets these companies apart. This research approach would be better suited toward getting information from small contractors rather than the randomly selected telephone interview that was done for this study.

The second part of the study focused on quantifying the synergistic effects between pairs of leading indicators from the perspective of an owner and that of a contractor through separate Delphi panels. It is interesting to note that from both perspectives, the leading indicator with the greatest overall synergistic impact was pre-task planning. Also, from either perspective the leading indicators with the least overall synergistic impact were found to be pre-task planning for vendor activities, vendor safety audits, and vendor exit debriefs.

The Delphi panel quantifying the pair-wise synergistic effects among the leading indicators from the perspective of the owner found a number of pairs with significant increases in effectiveness. Those pairs from the perspective of an owner and their increase in effectiveness are presented in Table 5.1.

Table 5.1 Most Significant Percent Increases in Effectiveness for Measuring Safety Performance from an Owner's Perspective

Leading indicator pairs		% increase
Project management team safety process involvement	Pre-task planning	60-69%
Worker observation process	Pre-task planning	55-64%
Project management team safety process involvement	Worker observation process	50-59%
Near-miss reporting	Project management team safety process involvement	50-59%
Project management team safety process involvement	Owner safety walkthroughs	50-59%
Project management team safety process involvement	Stop work authority	49-58%
Stop work authority	Pre-task planning	49-58%
Stop work authority	Housekeeping program	49-58%
Pre-task planning	Housekeeping program	49-58%
Pre-task planning	Owner participation in worker orientation sessions	49-58%
Pre-task planning	Foremen discussions and feedback meetings with owner's project manager	49-58%
Housekeeping program	Owner participation in worker orientation sessions	49-58%
Housekeeping program	Owner safety walkthroughs	49-58%
Near-miss reporting	Stop work authority	48-57%

It is estimated that this information has the potential to help owner companies that are looking to include contractual safety requirements regarding leading indicators or considering measuring their contractor's safety performance during the duration of the project.

The Delphi panel from the perspective of a contractor also found some select pairs that had significant increases in effectiveness when used in conjunction for measuring safety performance during a project. Those pairs from the perspective of a contractor and their increase in effectiveness are presented in Table 5.2.

Table 5.2 Most Significant Percent Increases in Effectiveness for Measuring Safety Performance from a Contractor's Perspective

Leading indicator pairs		% increase
Near-miss reporting	Pre-task planning	70-79%
Project management team safety process involvement	Pre-task planning	65-74%
Worker observation process	Pre-task planning	60-69%
Worker observation process	Housekeeping program	60-69%
Near-miss reporting	Owner participation in worker orientation sessions	60-69%
Pre-task planning	Housekeeping program	60-69%
Near-miss reporting	Project management team safety process involvement	50-59%
Near-miss reporting	Stop work authority	50-59%
Worker observation process	Auditing program	50-59%
Auditing program	Pre-task planning	50-59%
Auditing program	Housekeeping program	50-59%

By quantifying these relationships, the results from this study will help contractors that are beginning to monitor safety performance with leading indicators or wanting to enhance their current program.

There are interesting differences and similarities to note between the three phases of research. One of those included the barriers to implementing leading indicators between the small contractors and the two panels of experts. The greatest responses by small contractors not using leading indicators were found to be: unnecessary, cost, ineffective, does not apply to small contractors, and takes too much time. Responses from the two panels about the barriers to using leading indicators included challenges related to identifying and measuring the indicator, lack of management support, cost, measuring too many indicators, and leading indicators have not reached widespread use yet. These responses are interesting in several ways; first the small contractors often felt that the indicators did not apply specifically to them, indicating more research is needed into effective strategies for these firms. On the other hand, the panels representing larger companies felt leading indicators are applicable to larger projects, but the barrier comes from upper management and difficulty in understanding leading indicators because they are a relative new concept and have not yet reached widespread use.

The main differences that should be noted between the owner and contractor panels are the rank order of leading indicators' overall synergistic impact. First, the panels both found that pre-task planning, project management team safety process involvement, worker observations, and a housekeeping program had a significant overall synergistic impact; however the other indicators differed. From the perspective of the owner, the other leading indicators that had the greatest overall impact were: owner safety walk-throughs, owner participation in worker orientation session, and stop work authority. These views were not shared by the contractor panel who felt the other indicators with the most synergistic impact were near-miss reporting and an auditing program. These differences may illustrate that from the perspective of an owner they may feel their actions (i.e. owner safety walk-throughs and participation in worker orientation) have more of an impact than from the perspective of a contractor. Regardless the impact, these indicators related to the owner have the potential to overcome some of the main obstacles to leading indicator use that were found in the second and third phases of this study. Those relevant obstacles are: lack of upper management support and safety culture. Having a visible owner through attendance at the safety meetings and participating in safety walk-throughs would most likely improve the upper management support of the project towards safety which would further build the safety culture of the contractor. This understanding corroborates the finding of the Construction Users Roundtable which found the owner to have the greatest leverage in maintaining a safe project (CURT 2004).

The results provide valuable guidance from three phases of research that comprised the first study of its kind; however more research was found to be needed. First, for the safety performance of the construction industry to improve, research into effective strategies relevant to small contractors needs to be a priority. This sector of the industry has the worst fatality rate and has remained almost unchanged in the past five years. To date there has been little research activity concerning small contractor safety strategies. For this to change, innovative data collection methods need to be devised and tested to find the most effective way to gather information from small contractors. Secondly, the synergistic effects were quantified in the second and third phase of this study; however the individual effectiveness of each leading indicator remains unknown. A future research recommendation includes moderating a Delphi panel of experts to find the individual effectiveness of each indicator. Those results could be combined with the results from this study to help further with the selection of leading indicators to measure the safety performance of a construction project. Finally, this study only looked at the synergistic effects between pairs of indicators. It is estimated that there may be synergistic effects when more than two indicators are used for measuring safety performance of a project. Another opportunity for future research could evaluate these effects to determine whether there are diminishing returns in effectiveness as more indicators are used for measuring the safety performance of a project.

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Appendix A Leading indicators of construction safety (Baud 2012)

Safety Leading Indicators	References
% of daily toolbox safety meetings	Hinze and Figone 1988a; Jaselskis et al. 1996; Harper and Koehn 1998; Rajendran and Gambatese 2009
100% earplugs policy	Liska et al. 1993
100% fall protection	Liska et al. 1993 ; Chi et al. 2005
100% gloves policy	Liska et al. 1993; Harper and Koehn 1998
100% hard hat policy	Liska et al. 1993; Harper and Koehn 1998
100% reflective vest policy	Liska et al. 1993
100% safety glasses policy	Liska et al. 1993; Harper and Koehn 1998; Lombardi et al. 2009
100% steel-toed boots policy	Liska et al. 1993
10-hour OSHA training for company employees	McDonald et al. 2009; Rajendran and Gambatese 2009
Background check for every new employee	Baud 2012
Company-specific orientation for all new hires	Hinze and Harrison 1981; Lee 1991; Jaselskis et al. 1996; Tam and Fung 1996; Harper and Koehn 1998
Computer-based safety training	Evia 2011
Early project completion reward	Jolayemi 2001
Early-return-to-work policy	Baud 2012
Emergency response plan for the project	Meridian 1994; Findley et al. 2004; Hallowell and Gambatese 2009a; McDonald et al. 2009; Rajendran and Gambatese 2009
Employees' skills	Baud 2012
Established disciplinary program	Baud 2012
Fatigue management program	Hallowell 2010c
First aid log	Meridian 1994
Fit for duty	Meridian 1994
Foremen evaluation in safety performance	Levitt and Parker 1976; Hinze and Raboud 1988; Rajendran and Gambatese 2009
Foremen involvement in accident investigation	Liska et al. 1993; Meridian 1994
Foremen involvement in hazard assessment	Baud 2012
Foremen involvement in jobsite safety inspections and audits	Meridian 1994; Hinze and Gambatese 2003
Foremen involvement in lessons-learned/knowledge management	Baud 2012
Foremen involvement in policy creation and implementation	Baud 2012
Foremen involvement in safety committees	Baud 2012
Formal interviews for safety personnel	Hinze and Harrison 1981
Formal lessons-learned/ knowledge management program	Hallowell 2012
Full time safety manager on the project	Hinze and Figone 1988b; Sawacha et al. 1999; Findley et al. 2004; Abudayyeh et al. 2006; Huang and Hinze 2006; Hallowell and Gambatese 2009b; McDonald et al. 2009; Rajendran and Gambatese 2009
GC involvement in the investigation of subs injuries	Hinze and Figone 1988a,b
GC's project safety plan	Levitt et al. 1981; Samelson and Levitt 1982
Health & Safety (H&S) manual	Jaselskis et al. 1996
Heat and cold stress program	Baud 2012
Heavy equipment inspection and approval program	Baud 2012

Injury reporting and analysis program	Liska et al. 1993; Levitt and Samelson 1993; Tam and Fung 1996; McDonald et al. 2009; Rajendran and Gambatese 2009
In-person training and certification	Baud 2012
Job hazard analyses	Meridian 1994; Hinze 1997; Hallowell and Gambatese 2009a; McDonald et al. 2009; Rajendran and Gambatese 2009
Jobsite superintendent participation in new hire orientation	Hinze and Figone 1988a,b
Leadership development program	Slates 2008
Lock-out tag-out policy	Boylston 1982; Crawford 2003
Lump Sum or Costs-Plus contract	Kingsnorth 1986
Maintenance program for all equipment	Toole 2002
Management review of craft worker training	Toole 2002
Mandatory substance abuse program	Liska et al. 1993, Jaselskis et al. 1996; Hinze and Gambatese 2003; Findley et al. 2004; Hallowell and Gambatese 2009b; Rajendran and Gambatese 2009
Medical facilities on-site	Meridian 1994
Minimum ratio of craft workers to supervisors	Reed and Hinze 1986
Minimum ratio of number of safety supervisors to workers	Reed and Hinze 1986
Minimum ratio of safety professionals to workers	Reed and Hinze 1986
Monthly H&S training for supervisors	Baud 2012
Near-misses investigation	Liska et al. 1993; Huang and Hinze 2006; Rajendran and Gambatese 2009
No injuries reward or incentives	Levitt and Parker 1976; Liska et al. 1993; Krause and Hodson 1998; Opfer 1998; Flanders and Lawrence 1999; Hinze 2002; Hinze and Gambatese 2003
Noise measurement and mitigation policy	Rajendran and Gambatese 2009
On-site testing and skill evaluation of mobile equipment for craft workers	Rajendran and Gambatese 2009
Owner review and approval of Construction Management	Levitt et al. 1981; Samelson and Levitt 1982
Owner review of key contract H&S professionals	Samelson and Levitt 1982; Huang and Hinze 2006
Owner visibility in safety planning	Liska et al. 1993; Levitt and Samelson 1993
Participation of all contractors and major subs in safety meetings	Baud 2012
Past safety performance for foremen selection	Baud 2012
PPE inspection and maintenance policy	Baud 2012
Productivity incentive program	Hinze and Parker 1978; Hinze and Raboud 1988; Hinze and Figone 1988a; Sawacha et al. 1999
Project health and wellness reviews	Baud 2012
Quality requirements of lunchroom facilities	Baud 2012
Quality requirements of parking lot	Baud 2012
Quality requirements of restroom facilities	Baud 2012
Regular inspection and maintenance of all tools	Baud 2012
Regular scheduled meetings for safety personnel	Hinze 1997
Regularly scheduled equipment inspections	Baud 2012
Review of H&S manual by owner/CEO	Baud 2012
Root cause analysis program	Liska et al. 1993; Hinze et al. 1998; Abdelhamid and Everett 2000; Suraji et al. 2001; Toole 2002
Safe behavior reward and recognition	Liska et al. 1993; Laitinen and Ruohomaki 1996; Tam and Fung 1996; Krause and Hodson 1998; Opfer 1998, Flanders and Lawrence 1999; Hinze 2002; Hinze and Gambatese 2003

Safety during constructability reviews	Hinze and Wiegand 1992; Liska et al. 1993; Hinze and Gambatese 1996; Jergeas and Van der Put 2001; Huang and Hinze 2006; Rajendran and Gambatese 2009
Safety during design phase	Hinze 1991, 1994a,b; Hinze and Wiegand 1992; Liska et al. 1993; Hinze and Gambatese 1994; Coble 1997; Gambatese et al. 1997; Gambatese 1998, 2000; Hadikusumo and Rowlinson 2004; Toole 2002, 2005; Rajendran and Gambatese 2009
Safety goals development and communication	Levitt and Samelson 1993; Meridian 1994
Safety in scheduling	Levitt and Parker 1976; Hinze and Raboud 1988; Hinze and Figone 1988a,b; Liska et al. 1993; Kartam 1997; Gambatese et al. 1997; Gambatese 2000; Chantawit et al. 2005; Hinze et al. 2005a; Yi and Langford 2006; Rajendran and Gambatese 2009; Sacks et al. 2009
Safety instructor for the project	Baud 2012
Safety leadership training for foremen	Baud 2012
Safety mentoring program for workers	Hinze and Harrison 1981
Safety orientation test	Harper and Koehn 1998
Safety perception surveys completion by foremen	McDonald 2006; Choudhry et al. 2009; Hallowell 2010c
Safety training history for all personnel	Samelson and Levitt 1982
Site-specific safety orientation for all employees	Samelson and Levitt 1982; Liska et al. 1993; Levitt and Samelson 1993; Meridian 1994; Hinze 1997; Abudayyeh et al. 2006; Harper and Koehn 1998; Hallowell and Gambatese 2009a; McDonald et al. 2009; Rajendran and Gambatese 2009
Site-specific safety orientation for all managers	Liska et al. 1993; Meridian 1994; Abudayyeh et al. 2006; Harper and Koehn 1998; McDonald et al. 2009; Hallowell and Gambatese 2009b; Rajendran and Gambatese 2009
Specific safety prequalification	Levitt and Samelson 1993; Gambatese 2000
Stop work policy	Rajendran and Gambatese 2009
Stretch and flex program for workers	Rajendran and Gambatese 2009
Subs participation in General Contractor (GC)'s orientation and training	Hinze and Figone 1988a,b; Meridian 1994; Jaselskis et al. 1996; Hinze 1997
Subs prequalification on safety	Gambatese 2000
Subs safety standards compared to GC	Hinze and Figone 1988a,b; Hinze and Talley 1988
Un-announced random Drug & Alcohol program	Liska et al. 1993; Hinze and Gambatese 2003
Union workers on site	Sawacha et al. 1999; Gillen et al. 2002
Vendor safety orientation	Baud 2012
Work hours restrictions	Tucker 1986
Worker hydration program	Baud 2012
Workers involvement in accident investigations	Liska et al. 1993; Meridian 1994
Workers involvement in hazard assessment	Meridian 1994
Workers involvement in inspections and audits	Meridian 1994
Workers involvement in perception surveys	Choudhry et al. 2009; Hallowell 2010b
Workers involvement in policy creation and implementation	Meridian 1994
Workers involvement in pre-task safety planning	Liska et al. 1993
Workers involvement in safety committees	Meridian 1994; Harper and Koehn 1998; Findley et al. 2004
Worker-to-worker observation program	Kathirgamanathan and Wong 2005; Kalia 2010
Written site-safety plan	Hinze 1997; Rajendran and Gambatese 2009
Zero tolerance policy	Baud 2012

Appendix B Delphi panel qualification introductory survey

INTRODUCTORY SURVEY

Thank you once again for serving on the Delphi panel for this research. Your participation is greatly appreciated! The purpose of this introductory survey is to objectively confirm your status as an expert in the field of construction safety based on your professional experience and achievements. Please answer all of the following questions to the best of your ability. Fields that require a response have been highlighted in yellow. Please place an "X" in the appropriate boxes or fill in the appropriate fields. When you have finished answering all of the questions please email your response, in Word format, to calhoun@uaa.alaska.edu. This survey is intended to be completed in less than 15 minutes.

PERSONAL INFORMATION

The following questions are intended to confirm your position as an expert. Once validated, the Delphi responses will be anonymous and all members will be treated equally.

Name	
Current Employer	
Position	
Company Annual Revenue	
State	
Owner, GC, Sub, Vendor, Design/Build, CM?	
Use safety leading indicators (proactive measures of safey)	
Approx number of projects safety leading indicators have been used on?	

ACADEMIC INFORMATION

Please indicate the degrees that you have earned from accredited institutions of higher learning:

Degree	Major / Field of Concentration
None	
Associates	
Bachelors	
Masters	
Doctorate	

CONFERENCE PARTICIPATION

Please indicate your conference activity **in the topics of safety, health and risk management**:

Activity number of presentations	Approximate Number
Conference presentations	

PROFESSIONAL EXPERIENCE

Please indicate your experience in the construction industry:

Position	Approximate Number of Years
Laborer	
Foreman	
Superintendent	
Safety and Health Management	
Risk Management	
Upper Management (Owner, GC, CM or Sub)	
Project Engineer	
Architect	
Other (please specify)	
Other (please specify)	

Please indicate your professional licensure/certification:

Licensure or certification	Please place an "X" where appropriate
Professional Engineer (PE)	
Certified Safety Professional (CSP)	
Certified Industrial Hygienist (CIH)	
Associated Risk Manager (ARM)	
Licensed Architect (AIA)	
Other (please specify)	

Please list any safety, health or risk management committees of which you are or have been a member. Please also indicate if you are or have been the Chair of a particular committee.

Committee Name	Were you a Chair (past or present) of this committee?

If you believe that there is an element of your professional experience that helps to qualify you as an expert that cannot be classified in a previous category, please list and briefly describe it here.

Put an "X" next to the metrics below that you feel are proactive measures (i.e. leading indicators) that can be used on construction projects to monitor safety

Proactive measures (i.e. safety leading indicator	If yes, place an X
Near miss/near hit	
Attendance at safety meeting	
Number of safety meetings	
First aid on-site	
Recordable injury rate (RIR)	

What are the main obstacles to using proactive measures of safety (i.e. safety leading indicators)?

What are the strategies to overcome these obstacles?

Thank you for taking the time to fill out this introductory survey. The first round of the Delphi process will begin on December 15, 2014. If you have any questions about this survey or about the research project in general, please do not hesitate to contact me:

Matthew Calhoun

Ph.D. Candidate
College of Engineering and Mines
University of Alaska Fairbanks

Tel.: 907-223-8266; calhoun@uaa.alaska.edu

THANK YOU VERY MUCH FOR YOUR TIME!!

Appendix C Delphi survey Round 1 example

ROUND 1 – DELPHI SURVEY

Thank you for taking the time to complete Round 1 of this Delphi survey. This survey is intended to take approximately 20-25 minutes. When you have finished answering all of the questions, please email your response to calhoun@uaa.alaska.edu.

INSTRUCTIONS: Please answer all of the following questions to the best of your ability using your experience and judgment. Indicate your response by placing an "X" in the appropriate boxes. The survey requests that you indicate the percent increase in effectiveness that Safety leading indicator X has when paired with Safety leading indicator Y for predicting safety performance. There are fifteen safety leading indicators listed below with an example of how they could be measured and possible resources needed (Hallowell et al. 2013).

Safety leading indicators	Example of measurement	Example of resources required
Near miss reporting	Monitor a 3-month moving average of the number of near misses per 200,000 worker-hours of exposure.	A standardized form for reporting near misses is required and personnel must be available to input/ track data.
Project management team safety process involvement	Frequency of participation of project management team members in field safety activities.	Time commitment from the project management team members. A scorecard would be a simple mechanism by which each member's involvement would be visibly documented.
Worker observation process	A 3-month moving average of the number of safety observations conducted per 200,000 work-hours of exposure.	Initially time is required to train observers. All jobsite personnel should be educated on the intent and proper protocol for observation. Personnel available to collect and enter data.
Stop work authority	The number of times that the stop work authority is exercised per 200,000 worker hours.	The stop work authority is clearly communicated to workers in initial orientation and at regular intervals throughout each project.
Auditing program	Percentage of audited items in compliance	Data must be regularly documented for tracking, trending, and closing of corrective actions. Personnel required to input and track data.
Pre-task planning	The percentage of pre-task plans prepared for work tasks. Management may wish to also measure the quality of the meetings using a rubric.	Pre-task planning forms should be prepared and be readily available to all field crews. Personnel must be assigned to evaluate and score the pre-task plans along with input and track data.
Housekeeping program	A rubric for consistent scoring should be created as housekeeping is somewhat qualitative. Scores may be generated and compared once a rubric is created.	Personnel must be assigned to input, track, and trend the results. Follow-up efforts will be required to ensure that corrective actions are promptly implemented.

Owner participation in worker orientation sessions	Percentage of orientation sessions in which the owner's project manager is an active participant.	The owner's project manager should prepare an outline or script to ensure that specific points are made and that consistent expectations are shared at the orientation sessions.
Foremen discussions and feedback meetings with owner's project manager	Frequency of meetings and percentage of key members in attendance at each meeting. Total number of foremen attending the meetings versus the number of foremen on the project site. Percentage of action items that are closed on or before the target date.	A standing agenda should be maintained and meeting minutes should be kept. Action items should be enumerated and the close-out of these action items is to be tracked.
Owner safety walkthroughs	The frequency of walkthroughs per 200,000 worker-hours.	A walkthrough checklist is needed to operationalize the observation and recording process. Personnel time is required for walkthroughs.
Pre-task planning for vendor activities	Percentage of vendors entering site with appropriate safety planning as described.	Supplier time (dependent on material supplied), contractor time (recording and processing), and management commitment are required.
Vendor safety audits	The percentage of vendors in compliance with site policies and procedures.	Staff time will be required to prepare and conduct audits and management time will be needed to review and respond to audit results.
Vendor exit debrief	Percentage of exit interviews that include identified hazards, unsafe behaviors or incidents.	Measuring and monitoring this indicator requires time to gather information from vendors upon their departure. Entry to the site should be controlled and properly staffed.
Positive feedback/reinforcement	A rubric for consistent scoring should be created as housekeeping is somewhat qualitative. Scores may be generated and compared once a rubric is created.	Workers must embrace the zero accident vision and not feel there will be negative consequences for open dialogue. Personnel must be available for input and tracking.
Attendance at safety meetings	Percentage of attendees and their roles at safety meetings.	Personnel must be assigned to input, track, and trend the results.

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **NEAR MISSES** combined with measuring each of the safety leading indicators.

Measurement of the following Safety Leading Indicator	**Percent increase in effectiveness that measuring NEAR MISSES combined with measuring each of the following:** % Increase in Effectiveness for predicting safety performance												
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Project mgmt. team safety process involvement													
Worker observation process													
Stop work authority													
Auditing program													
Pre-task planning													
Housekeeping program													
Owner's participation in worker orientation sessions													
Foremen discussions and feedback meetings with the owner's PM													
Owner safety walkthroughs													
Pre-task planning for vendor activities													
Vendor safety audits													
Vendor exit debrief													
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **PROJECT MANAGEMENT TEAM SAFETY PROCESS INVOLVEMENT** combined with measuring each of the safety leading indicators below.

Measurement of the following Safety Leading Indicator	**Percent increase in effectiveness that measuring PROJECT MANAGEMENT TEAM SAFETY PROCESS INVOLVEMENT combined with measuring each of the following:** % Increase in Effectiveness for predicting safety performance												
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Worker observation process													
Stop work authority													
Auditing program													
Pre-task planning													
Housekeeping program													
Owner's participation in worker orientation sessions													
Foremen discussions and feedback meetings with the owner's PM													
Owner safety walkthroughs													
Pre-task planning for vendor activities													
Vendor safety audits													
Vendor exit debrief													
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **WORKER OBSERVATION PROCESS** combined with measuring each of the safety leading indicators below.

		Percent increase in effectiveness that measuring WORKER OBSERVATION PROCESS combined with measuring each of the following:											
Measurement of the following Safety Leading Indicator		% Increase in Effectiveness for predicting safety performance											
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Stop work authority													
Auditing program													
Pre-task planning													
Housekeeping program													
Owner's participation in worker orientation sessions													
Foremen discussions and feedback meetings with the owner's PM													
Owner safety walkthroughs													
Pre-task planning for vendor activities													
Vendor safety audits													
Vendor exit debrief													
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **STOP WORK AUTHORITY** combined with measuring each of the safety leading indicators below.

		Percent increase in effectiveness that measuring STOP WORK AUTHORITY combined with measuring each of the following:											
Measurement of the following Safety Leading Indicator		% Increase in Effectiveness for predicting safety performance											
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Auditing program													
Pre-task planning													
Housekeeping program													
Owner's participation in worker orientation sessions													
Foremen discussions and feedback meetings with the owner's PM													
Owner safety walkthroughs													
Pre-task planning for vendor activities													
Vendor safety audits													
Vendor exit debrief													
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **AUDITING PROGRAM** combined with measuring each of the safety leading indicators below.

	Percent increase in effectiveness that measuring AUDITING PROGRAM combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator		% Increase in Effectiveness for predicting safety performance											
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Pre-task planning													
Housekeeping program													
Owner's participation in worker orientation sessions													
Foremen discussions and feedback meetings with the owner's PM													
Owner safety walkthroughs													
Pre-task planning for vendor activities													
Vendor safety audits													
Vendor exit debrief													
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **PRE-TASK PLANNING** combined with measuring each of the safety leading indicators below.

	Percent increase in effectiveness that measuring PRE-TASK PLANNING combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator		% Increase in Effectiveness for predicting safety performance											
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Housekeeping program													
Owner's participation in worker orientation sessions													
Foremen discussions and feedback meetings with the owner's PM													
Owner safety walkthroughs													
Pre-task planning for vendor activities													
Vendor safety audits													
Vendor exit debrief													
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **HOUSEKEEPING** combined with measuring each of the safety leading indicators below.

Measurement of the following Safety Leading Indicator	Percent increase in effectiveness that measuring HOUSEKEEPING combined with measuring each of the following: % Increase in Effectiveness for predicting safety performance												
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Owner's participation in worker orientation sessions													
Foremen discussions and feedback meetings with the owner's PM													
Owner safety walkthroughs													
Pre-task planning for vendor activities													
Vendor safety audits													
Vendor exit debrief													
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **OWNER'S PARTICIPATION IN WORKER ORIENTATION SESSIONS** combined with measuring each of the safety leading indicators below.

Measurement of the following Safety Leading Indicator	Percent increase in effectiveness that measuring OWNER'S PARTICIPATION IN WORKER ORIENTATION SESSION combined with measuring each of the following: % Increase in Effectiveness for predicting safety performance												
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Foremen discussions and feedback meetings with the owner's PM													
Owner safety walkthroughs													
Pre-task planning for vendor activities													
Vendor safety audits													
Vendor exit debrief													
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **FOREMEN DISCUSSIONS AND FEEDBACK MEETINGS WITH THE OWNER'S PROJECT MANAGER** combined with measuring each of the safety leading indicators below.

		Percent increase in effectiveness that measuring FOREMEN DISCUSSIONS AND FEEDBACK MEETINGS WITH THE OWNER'S PROJECT MANAGER combined with measuring each of the following:											
Measurement of the following Safety Leading Indicator		% Increase in Effectiveness for predicting safety performance											
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Owner safety walkthroughs													
Pre-task planning for vendor activities													
Vendor safety audits													
Vendor exit debrief													
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **OWNER SAFETY WALKTHROUGHS** combined with measuring each of the safety leading indicators below.

		Percent increase in effectiveness that measuring OWNER SAFETY WALKTHROUGHS combined with measuring each of the following:											
Measurement of the following Safety Leading Indicator		% Increase in Effectiveness for predicting safety performance											
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Pre-task planning for vendor activities													
Vendor safety audits													
Vendor exit debrief													
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **PRE-TASK PLANNING FOR VENDOR ACTIVITIES** combined with measuring each of the safety leading indicators below.

		Percent increase in effectiveness that measuring PRE-TASK PLANNING FOR VENDOR ACTIVITIES combined with measuring each of the following:											
Measurement of the following Safety Leading Indicator		% Increase in Effectiveness for predicting safety performance											
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Vendor safety audits													
Vendor exit debrief													
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **VENDOR SAFETY AUDITS** combined with measuring each of the safety leading indicators below.

		Percent increase in effectiveness that measuring VENDOR SAFETY AUDITS combined with measuring each of the following:											
Measurement of the following Safety Leading Indicator		% Increase in Effectiveness for predicting safety performance											
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Vendor exit debrief													
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **VENDOR EXIT DEBRIEF** combined with measuring each of the safety leading indicators below.

		Percent increase in effectiveness that measuring VENDOR EXIT DEBRIEF combined with measuring each of the following:											
Measurement of the following Safety Leading Indicator		% Increase in Effectiveness for predicting safety performance											
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Positive feedback/reinforcement													
Attendance at safety meetings													

DIRECTIONS: Put an "**X**" in the box that indicates the percent increase in effectiveness for predicting safety performance when measuring **POSITIVE FEEDBACK AND REINFORCEMENT** combined with measuring each of the safety leading indicators below.

		Percent increase in effectiveness that measuring POSITIVE FEEDBACK AND REINFORCEMENT combined with measuring each of the following:											
Measurement of the following Safety Leading Indicator		% Increase in Effectiveness for predicting safety performance											
	<0	0	10	20	30	40	50	60	70	80	90	100	>100
Attendance at safety meetings													

Thank you for completing Round 1 of the Delphi Survey. Your survey responses can be emailed to calhoun@uaa.alaska.edu or printed and mailed to:

University of Alaska Anchorage
3211 Providence Drive
ANSEP 200D1
Attn: Matt Calhoun (Graduate Student)
Anchorage, AK 99508-4614

After all Delphi participants have completed the Round 1 survey, the results will be reported to you with the median response and range. In Round 2 you will be given the opportunity to change your response or provide feedback to the group anonymously. Round 2 is scheduled to start Monday, January 26. Thank you again for your time in this study.

Appendix D Delphi survey Round 2 example

ROUND 2 – DELPHI SURVEY

Thank you for taking completing the Round 1 Delphi survey. I recognize that the survey required a significant time investment. I appreciate your time and effort. This Round 2 survey continues the Delphi process for this study. The purpose of Round 2 is to provide you with the opportunity to change your response, if desired, given the median group response for each category.

This survey is intended to take approximately 20 minutes as you are only being asked to review your previous responses given the collective group median. When you have finished answering all of the questions, please email your response to calhoun@uaa.alaska.edu.

INSTRUCTIONS: For each safety leading indicator you will see 2 values: your response from the Round 1 survey (indicated with a highlighted box), and the group median from the Round 1 survey indicated in the column to the far right hand of each table. Please take one of the following three actions for each category:

1. **Accept the group median response by leaving the field completely unchanged.**
2. **Maintain your original response by placing an 'X' in the highlighted field*.**
3. **Indicate a new response by placing an 'X' in the appropriate field*.**

*If your response is more than ten percent above or below the group median please provide a reason for you outlying response in the field provided below.

The Round 1 survey provided you with the safety leading indicators being evaluated, a potential way to measure the leading indicator, and possible resources that may be required (Hallowell et al. 2013). If at any time you would like to review these, you will find them at the end of this survey.

DIRECTIONS: Please do one of the following: **(1)**accept the group median response by leaving the field completely unchanged, **(2)**maintain your original response by placing an 'X' in the highlighted field*, **(3)**indicate a new response by placing an 'X' in the appropriate field*.

*If your response is more than 10 percent above or below the group median please provide a reason for you outlying response in the field provided.

Measurement of the following Safety Leading Indicator	Negative Influence	**Percent increase in effectiveness that measuring NEAR MISSES combined with measuring each of the following:** % Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Project mgmt. team safety process involvement														15
Worker observation process														75
Stop work authority														50
Auditing program														15
Pre-task planning														35
Housekeeping program														50
Owner's participation in worker orientation sessions														45
Foremen discussions and feedback meetings with the owner's PM														10
Owner safety walkthroughs														15
Pre-task planning for vendor activities														60
Vendor safety audits														50
Vendor exit debrief														35
Positive feedback/reinforcement														35
Attendance at safety meetings														60

Reason(s) for outlying response(s):

		Percent increase in effectiveness that measuring PROJECT MANAGEMENT TEAM SAFETY PROCESS INVOLVEMENT combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Worker observation process														15
Stop work authority														75
Auditing program														50
Pre-task planning														15
Housekeeping program														35
Owner's participation in worker orientation sessions														50
Foremen discussions and feedback meetings with the owner's PM														45
Owner safety walkthroughs														10
Pre-task planning for vendor activities														15
Vendor safety audits														60
Vendor exit debrief														50
Positive feedback/reinforcement														35
Attendance at safety meetings														35

Reason(s) for outlying response(s):

		Percent increase in effectiveness that measuring WORKER OBSERVATION PROCESS combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Stop work authority														15
Auditing program														75
Pre-task planning														50
Housekeeping program														15
Owner's participation in worker orientation sessions														35
Foremen discussions and feedback meetings with the owner's PM														50
Owner safety walkthroughs														45
Pre-task planning for vendor activities														10
Vendor safety audits														15
Vendor exit debrief														60
Positive feedback/reinforcement														50
Attendance at safety meetings														35

Reason(s) for outlying response(s):

		Percent increase in effectiveness that measuring STOP WORK AUTHORITY combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Auditing program														15
Pre-task planning														75
Housekeeping program														50
Owner's participation in worker orientation sessions														15
Foremen discussions and feedback meetings with the owner's PM														35
Owner safety walkthroughs														50
Pre-task planning for vendor activities														45
Vendor safety audits														10
Vendor exit debrief														15
Positive feedback/reinforcement														60
Attendance at safety meetings														50

Reason(s) for outlying response(s):

		Percent increase in effectiveness that measuring AUDITING PROGRAM combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Pre-task planning														15
Housekeeping program														75
Owner's participation in worker orientation sessions														50
Foremen discussions and feedback meetings with the owner's PM														15
Owner safety walkthroughs														35
Pre-task planning for vendor activities														50
Vendor safety audits														45
Vendor exit debrief														10
Positive feedback/reinforcement														15
Attendance at safety meetings														60

Reason(s) for outlying response(s):

		Percent increase in effectiveness that measuring PRE-TASK PLANNING combined with measuring each of the following:											
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance											Median
		0	10	20	30	40	50	60	70	80	90	100	>100
Housekeeping program													15
Owner's participation in worker orientation sessions													75
Foremen discussions and feedback meetings with the owner's PM													50
Owner safety walkthroughs													15
Pre-task planning for vendor activities													35
Vendor safety audits													50
Vendor exit debrief													45
Positive feedback/reinforcement													10
Attendance at safety meetings													15

Reason(s) for outlying response(s):

		Percent increase in effectiveness that measuring HOUSEKEEPING combined with measuring each of the following:											
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance											Median
		0	10	20	30	40	50	60	70	80	90	100	>100
Owner's participation in worker orientation sessions													15
Foremen discussions and feedback meetings with the owner's PM													75
Owner safety walkthroughs													50
Pre-task planning for vendor activities													15
Vendor safety audits													35
Vendor exit debrief													50
Positive feedback/reinforcement													45
Attendance at safety meetings													10

Reason(s) for outlying response(s):

		Percent increase in effectiveness that measuring **OWNER'S PARTICIPATION IN WORKER ORIENTATION SESSION** combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Foremen discussions and feedback meetings with the owner's PM														15
Owner safety walkthroughs														75
Pre-task planning for vendor activities														50
Vendor safety audits														15
Vendor exit debrief														35
Positive feedback/reinforcement														50
Attendance at safety meetings														45

Reason(s) for outlying response(s):

		Percent increase in effectiveness that measuring **FOREMEN DISCUSSIONS AND FEEDBACK MEETINGS WITH THE OWNER'S PROJECT MANAGER** combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Owner safety walkthroughs														15
Pre-task planning for vendor activities														75
Vendor safety audits														50
Vendor exit debrief														15
Positive feedback/reinforcement														35
Attendance at safety meetings														50

Reason(s) for outlying response(s):

Percent increase in effectiveness that measuring OWNER SAFETY WALKTHROUGHS combined with measuring each of the following:

Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Pre-task planning for vendor activities														15
Vendor safety audits														75
Vendor exit debrief														50
Positive feedback/reinforcement														15
Attendance at safety meetings														35

Reason(s) for outlying response(s):

Percent increase in effectiveness that measuring PRE-TASK PLANNING FOR VENDOR ACTIVITIES combined with measuring each of the following:

Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Vendor safety audits														15
Vendor exit debrief														75
Positive feedback/reinforcement														50
Attendance at safety meetings														15

Reason(s) for outlying response(s):

Percent increase in effectiveness that measuring VENDOR SAFETY AUDITS combined with measuring each of the following:

Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Vendor exit debrief														15
Positive feedback/reinforcement														75
Attendance at safety meetings														50

Reason(s) for outlying response(s):

		Percent increase in effectiveness that measuring VENDOR EXIT DEBRIEF combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance											Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Positive feedback/reinforcement														15
Attendance at safety meetings														75

Reason(s) for outlying response(s):

		Percent increase in effectiveness that measuring POSITIVE FEEDBACK AND REINFORCEMENT combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Attendance at safety meetings														15

Reason(s) for outlying response(s):

Thank you for completing Round 2 of the Delphi Survey. Your survey responses can be emailed to calhoun@uaa.alaska.edu or printed and mailed to:

University of Alaska Anchorage
3211 Providence Drive
ANSEP 200D1
Attn: Matt Calhoun (Graduate Student)
Anchorage, AK 99508-4614

After all Delphi participants have completed the Round 2 survey, the results will be reported to you with the median response. In the final Round 3 you will be given the opportunity to change your response again. Round 3 is scheduled to start Monday, February 16. Thank you again for your time in this study.

Safety leading indicators	Example of measurement	Example of resources required
Near miss reporting	Monitor a 3-month moving average of the number of near misses per 200,000 worker-hours of exposure.	A standardized form for reporting near misses is required and personnel must be available to input/ track data.
Project management team safety process involvement	Frequency of participation of project management team members in field safety activities.	Time commitment from the project management team members. A scorecard would be a simple mechanism by which each member's involvement would be visibly documented.
Worker observation process	A 3-month moving average of the number of safety observations conducted per 200,000 work-hours of exposure.	Initially time is required to train observers. All jobsite personnel should be educated on the intent and proper protocol for observation. Personnel available to collect and enter data.
Stop work authority	The number of times that the stop work authority is exercised per 200,000 worker hours.	The stop work authority is clearly communicated to workers in initial orientation and at regular intervals throughout each project.
Auditing program	Percentage of audited items in compliance	Data must be regularly documented for tracking, trending, and closing of corrective actions. Personnel required to input and track data.
Pre-task planning	The percentage of pre-task plans prepared for work tasks. Management may wish to also measure the quality of the meetings using a rubric.	Pre-task planning forms should be prepared and be readily available to all field crews. Personnel must be assigned to evaluate and score the pre-task plans along with input and track data.
Housekeeping program	A rubric for consistent scoring should be created as housekeeping is somewhat qualitative. Scores may be generated and compared once a rubric is created.	Personnel must be assigned to input, track, and trend the results. Follow-up efforts will be required to ensure that corrective actions are promptly implemented.
Owner participation in worker orientation sessions	Percentage of orientation sessions in which the owner's project manager is an active participant.	The owner's project manager should prepare an outline or script to ensure that specific points are made and that consistent expectations are shared at the orientation sessions.
Foremen discussions and feedback meetings with owner's project manager	Frequency of meetings and percentage of key members in attendance at each meeting. Total number of foremen attending the meetings versus the number of foremen on the project site. Percentage of action items that are closed on or before the target date.	A standing agenda should be maintained and meeting minutes should be kept. Action items should be enumerated and the close-out of these action items is to be tracked.
Owner safety walkthroughs	The frequency of walkthroughs per 200,000 worker-hours.	A walkthrough checklist is needed to operationalize the observation and recording process. Personnel time is required for walkthroughs.
Pre-task planning for vendor activities	Percentage of vendors entering site with appropriate safety planning as described.	Supplier time (dependent on material supplied), contractor time (recording and processing), and management commitment are required.

Vendor safety audits	The percentage of vendors in compliance with site policies and procedures.	Staff time will be required to prepare and conduct audits and management time will be needed to review and respond to audit results.
Vendor exit debrief	Percentage of exit interviews that include identified hazards, unsafe behaviors or incidents.	Measuring and monitoring this indicator requires time to gather information from vendors upon their departure. Entry to the site should be controlled and properly staffed.
Positive feedback/reinforcement	A rubric for consistent scoring should be created as housekeeping is somewhat qualitative. Scores may be generated and compared once a rubric is created.	Workers must embrace the zero accident vision and not feel there will be negative consequences for open dialogue. Personnel must be available for input and tracking.
Attendance at safety meetings	Percentage of attendees and their roles at safety meetings.	Personnel must be assigned to input, track, and trend the results.

Appendix E Delphi survey Round 3 example

ROUND 3 – DELPHI SURVEY

Thank you for completing the Round 2 Delphi survey. We appreciate your time and effort. This Round 3 survey concludes the Delphi process for this study. The purpose of Round 3 is to provide you with a final opportunity to change your response, if desired, given the median group response and reasons for outlying responses for each pair combination.

This survey is intended to take approximately 20 minutes as you are only being asked to review your previous responses given the collective group median. When you have finished answering all of the questions, please email your response to calhoun@uaa.alaska.edu.

INSTRUCTIONS: The instructions for this survey are nearly identical to that of the Round 2 survey. The only difference between this survey and the Round 2 survey is the reasons provided at the end of each page. In Round 2 all panelists were asked to provide reasons if their responses were more than ten percent from the median. Please review the reasons provided by other expert panelists and consider them in your final response.

For each safety leading indicator you will see 2 values: your response from the Round 2 survey (indicated with a yellow highlighted box), and the group median from the Round 2 survey indicated in the column to the far right hand of each table. Please take one of the following three actions for each category:

1. **Accept the group median response by leaving all fields completely unchanged.**
2. **Maintain your original response by placing an 'X' in the highlighted field*.**
3. **Indicate a new response by placing an 'X' in the appropriate field*.**

*If your final response is more than ten percent above or below the group median please provide a reason for your outlying response in the field provided if you have not done so already.
*If your response is >100% or a negative influence, please quantify how many percent.

We **URGE** you to review and consider the median and the responses provided by the other expert panelists when considering your final responses for each safety leading indicator.

DIRECTIONS: Please do one of the following: **(1)**accept the group median response by leaving the field completely unchanged, **(2)**maintain your original response by placing an 'X' in the highlighted field*, **(3)**indicate a new response by placing an 'X' in the appropriate field*.

*If your response is more than 10 percent above or below the group median please provide a reason for you outlying response in the field provided.

		Percent increase in effectiveness that measuring NEAR MISSES combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Project mgmt. team safety process involvement														15
Worker observation process														75
Stop work authority														50
Auditing program														15
Pre-task planning														35
Housekeeping program														50
Owner's participation in worker orientation sessions														45
Foremen discussions and feedback meetings with the owner's PM														10
Owner safety walkthroughs														15
Pre-task planning for vendor activities														60
Vendor safety audits														50
Vendor exit debrief														35
Positive feedback/reinforcement														35
Attendance at safety meetings														60

Reason(s) for outlying response(s): Near misses is a lagging indicator, Measuring positive feedback and reinforcement is difficult

		Percent increase in effectiveness that measuring **PROJECT MANAGEMENT TEAM SAFETY PROCESS INVOLVEMENT** combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Worker observation process														15
Stop work authority														75
Auditing program														50
Pre-task planning														15
Housekeeping program														35
Owner's participation in worker orientation sessions														50
Foremen discussions and feedback meetings with the owner's PM														45
Owner safety walkthroughs														10
Pre-task planning for vendor activities														15
Vendor safety audits														60
Vendor exit debrief														50
Positive feedback/reinforcement														35
Attendance at safety meetings														35

Reason(s) for outlying response(s): Vendor debriefing is ineffective

		Percent increase in effectiveness that measuring **WORKER OBSERVATION PROCESS** combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Stop work authority														15
Auditing program														75
Pre-task planning														50
Housekeeping program														15
Owner's participation in worker orientation sessions														35
Foremen discussions and feedback meetings with the owner's PM														50
Owner safety walkthroughs														45
Pre-task planning for vendor activities														10
Vendor safety audits														15
Vendor exit debrief														60
Positive feedback/reinforcement														50
Attendance at safety meetings														35

Reason(s) for outlying response(s): If the workers are not onboard with the safety culture there will not be a 75% increase in effectiveness when combined with an auditing program.

Percent increase in effectiveness that measuring STOP WORK AUTHORITY combined with measuring each of the following:

Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Auditing program														15
Pre-task planning														75
Housekeeping program														50
Owner's participation in worker orientation sessions														15
Foremen discussions and feedback meetings with the owner's PM														35
Owner safety walkthroughs														50
Pre-task planning for vendor activities														45
Vendor safety audits														10
Vendor exit debrief														15
Positive feedback/reinforcement														60
Attendance at safety meetings														50

Reason(s) for outlying response(s): Stop work authority does not entail positive feedback/reinforcement usually.

Percent increase in effectiveness that measuring AUDITING PROGRAM combined with measuring each of the following:

Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Pre-task planning														15
Housekeeping program														75
Owner's participation in worker orientation sessions														50
Foremen discussions and feedback meetings with the owner's PM														15
Owner safety walkthroughs														35
Pre-task planning for vendor activities														50
Vendor safety audits														45
Vendor exit debrief														10
Positive feedback/reinforcement														15
Attendance at safety meetings														60

Reason(s) for outlying response(s): Auditing and vendor safety audits are the same.

Percent increase in effectiveness that measuring PRE-TASK PLANNING combined with measuring each of the following:

Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Housekeeping program														15
Owner's participation in worker orientation sessions														75
Foremen discussions and feedback meetings with the owner's PM														50
Owner safety walkthroughs														15
Pre-task planning for vendor activities														35
Vendor safety audits														50
Vendor exit debrief														45
Positive feedback/reinforcement														10
Attendance at safety meetings														15

Reason(s) for outlying response(s): Owners do not provide a 75% increase in effectiveness when combined with measuring pre-task planning.

Percent increase in effectiveness that measuring HOUSEKEEPING combined with measuring each of the following:

Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Owner's participation in worker orientation sessions														15
Foremen discussions and feedback meetings with the owner's PM														75
Owner safety walkthroughs														50
Pre-task planning for vendor activities														15
Vendor safety audits														35
Vendor exit debrief														50
Positive feedback/reinforcement														45
Attendance at safety meetings														10

Reason(s) for outlying response(s): Vendor exit debriefs are the least effective leading indicator of a potential accident.

Percent increase in effectiveness that measuring OWNER'S PARTICIPATION IN WORKER ORIENTATION SESSION combined with measuring each of the following:

Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Foremen discussions and feedback meetings with the owner's PM														15
Owner safety walkthroughs														75
Pre-task planning for vendor activities														50
Vendor safety audits														15
Vendor exit debrief														35
Positive feedback/reinforcement														50
Attendance at safety meetings														45

Reason(s) for outlying response(s):

Percent increase in effectiveness that measuring FOREMEN DISCUSSIONS AND FEEDBACK MEETINGS WITH THE OWNER'S PROJECT MANAGER combined with measuring each of the following:

Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Owner safety walkthroughs														15
Pre-task planning for vendor activities														75
Vendor safety audits														50
Vendor exit debrief														15
Positive feedback/reinforcement														35
Attendance at safety meetings														50

Reason(s) for outlying response(s): Owners can provide a visible safety culture, starts from the top.

Percent increase in effectiveness that measuring OWNER SAFETY WALKTHROUGHS combined with measuring each of the following:

Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Pre-task planning for vendor activities														15
Vendor safety audits														75
Vendor exit debrief														50
Positive feedback/reinforcement														15
Attendance at safety meetings														35

Reason(s) for outlying response(s): Safety leading indicators with vendors are the least effective in predicting a potential accident. I rate all of these low.

Percent increase in effectiveness that measuring PRE-TASK PLANNING FOR VENDOR ACTIVITIES combined with measuring each of the following:

Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Vendor safety audits														15
Vendor exit debrief														75
Positive feedback/reinforcement														50
Attendance at safety meetings														15

Reason(s) for outlying response(s): Safety leading indicators with vendors are the least effective in predicting a potential accident. I rate all of these low.

Percent increase in effectiveness that measuring VENDOR SAFETY AUDITS combined with measuring each of the following:

Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Vendor exit debrief														15
Positive feedback/reinforcement														75
Attendance at safety meetings														50

Reason(s) for outlying response(s):

		Percent increase in effectiveness that measuring VENDOR EXIT DEBRIEF combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Positive feedback/reinforcement														15
Attendance at safety meetings														75

Reason(s) for outlying response(s): Attendance is important, but participation is key at safety meetings

		Percent increase in effectiveness that measuring POSITIVE FEEDBACK AND REINFORCEMENT combined with measuring each of the following:												
Measurement of the following Safety Leading Indicator	Negative Influence	% Increase in Effectiveness for predicting safety performance												Median
		0	10	20	30	40	50	60	70	80	90	100	>100	
Attendance at safety meetings														15

Reason(s) for outlying response(s): Participation and not attendance is important.

Thank you for completing the final round of the Delphi Survey. Your survey responses can be emailed to calhoun@uaa.alaska.edu or printed and mailed to:

University of Alaska Anchorage
3211 Providence Drive
ANSEP 200D1
Attn: Matt Calhoun (Graduate Student)
Anchorage, AK 99508-4614

Thank you for your time and effort through this data collection process. The results will be compiled and published in an article that you will receive in the future. If you would not prefer an electronic copy, please provide your mailing address here:

THANK YOU VERY MUCH FOR YOUR TIME!!